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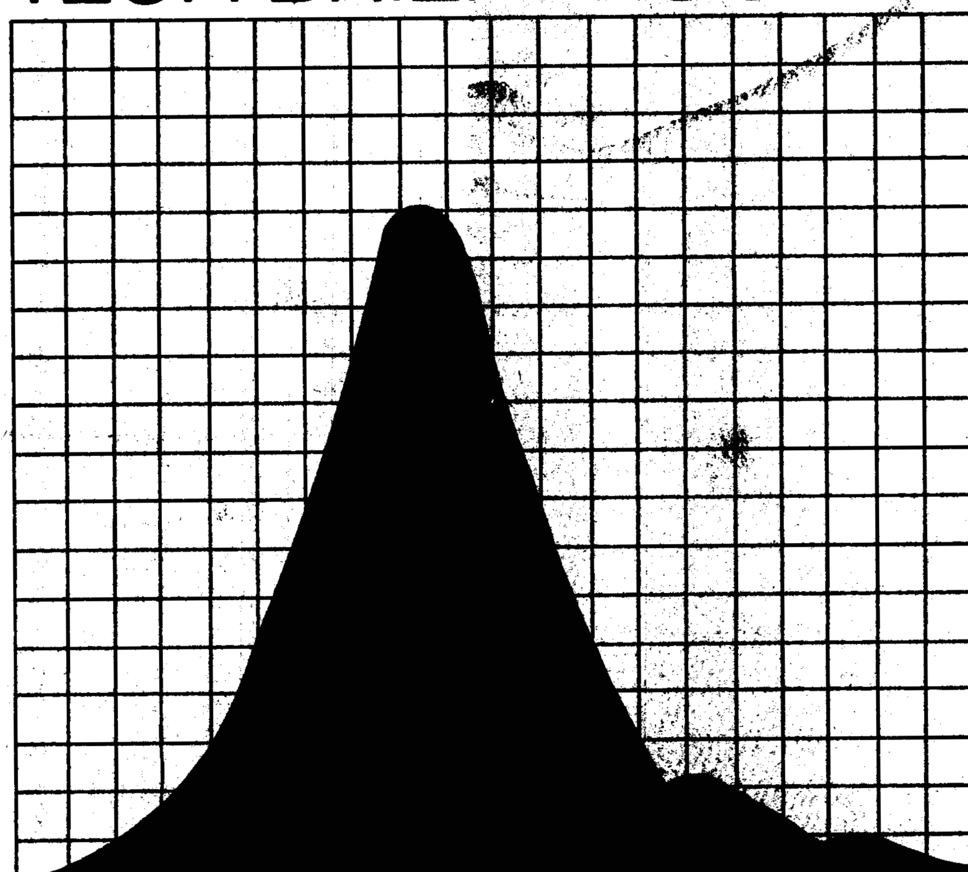
TECH BRIEF PROGRAM



COST BENEFIT EVALUATION

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NASA Tech Brief Program:

A Cost Benefit Evaluation

\- Prepared for -

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COST BENEFIT EVALUATION OF THE NASA TECH BRIEF PROGRAM -EXECUTIVE SUMMARY-

A cost benefit study of the NASA Tech Brief Program was conducted by the Denver Research Institute under contract to the Technology Utilization Office. Net benefits to public and private sector organizations due to Technical Support Package (TSP) requests between 1971 and mid-1976 were statistically estimated from random sample data. Program operating costs for the same time period were based on a unit cost analysis conducted by the TUO Program Evaluation and Control Division. The study objectives, methodology and results are summarized below.

Objectives

The Tech Brief/TSP Program is one of several operational mechanisms in the NASA Technology Utilization Program designed to transfer aerospace technology to both public and private sectors of the economy. It is, however, the oldest of these mechanisms, dating back to 1963, and has been one of the principal mainstays of NASA's technology transfer efforts over the years. Tech Briefs and other new technology announcements published by the TU Program have generated an annual average of over 26,000 inquiries since 1964. In addition, NASA has maintained, under contract, a data bank on requests and applications for new technology announced by Tech Briefs since 1968. This data bank contains over 120,000 entries and provides one of the most complete records of any technology transfer program operated by the Federal Government. Based on the availability of data and the request by Congress in the FY 1977 NASA Authorization Bill to conduct "a cost benefit follow-up analysis," the Agency elected to study its Tech Brief/TSP Program. The second objective for this study was to develop an evaluation method which satisfies the Office of Management and Budget guidelines for evaluation management.

Methodology

The study methodology included five important features:

- Existing data sources were reviewed and used to the fullest extent possible;
- Random sample selection was designed as a two-tiered process to start with available data;

- Data collection was through in-depth telephone interviews with a random sample of TSP recipients (n = 90);

- Data pre-analysis included four procedures to standardize the economic data; and

- Data analysis included the estimation of statistical distributions and expected net benefit values.

Between 1971 and mid-1976, 72,500 TSP requests due to Tech Briefs were recorded in the Transfer Research and Impact Studies (TRIS) Project Data Bank and 15,500 questionnaires had been returned from the ongoing six-month mail questionnaire survey. A two-tiered random sample of questionnaires was selected to assure a 95 percent confidence level for extrapolating the sample data to the entire population of TSP requests over the 5.5-year study period. Structured telephone interviews were conducted for the second tier random sample cells defined by request year and questionnaire responses.

The interview data included responses to the following questions:

(a) What specific use was made of the TSP (e.g., information source on solar energy or developed new computer control software for chemical processing)?

(b) What costs and gross benefits are directly attributed to the particular TSP, how were these quantities estimated, and when did they occur (e.g., number of hours saved in 1972 times the hourly rate including overhead)?

Only data which satisfied guidelines from the Federal Register (September 10, 1973) on costs and benefits were accepted for analysis. Standard statistical methods were used to estimate three probability distributions for the sample data, and an expected net benefit value per TSP request was calculated from these distributions. The expected net benefit per request was multiplied by the total requests to obtain the estimated total benefits from requests made between 1971 and mid-1976. This figure includes net benefits which are expected to occur after 1976, with some net benefit streams continuing into the 1980's.

NASA costs were calculated for each operating year by multiplying the total units (e.g., Tech Briefs published and mailed, TSP's reproduced) times the cost per unit. Unit costs were estimated by experienced TU personnel for all direct and indirect cost factors.

Total net benefits to users were then divided by aggregate NASA costs to calculate a benefit-to-cost ratio for Program operations between 1971 and mid-1976.

Results

The benefit-to-cost ratio for the Tech Brief/TSP Program is between 10:1 and about 11:1. The total NASA costs, discounted to 1976, were $6.4 million for the five and one-half year period. Total net benefits, discounted to 1976, were between $63.8 million and $72.5 million for requests made in the same time period. Federal tax revenues due to corporate taxes alone for these net benefits were estimated to be from one to two times the Program costs. Thus, the federal investment in the NASA Tech Brief/TSP Program appears to be more than recovered directly through taxes.

Based on interview results, TSP requests were characterized as having generated, or were expected to generate, secondary uses in four application modes. Each mode has an expected net benefit and probability of occurrence:

Mode 0 - no application, $0 net benefit; 34% chance.

Mode 1 - information acquisition only, $100 net benefit, 54% chance.

Mode 2 - improved process, product or service from using the technical content of the TSP, $4,900 to $5,000 net benefit, 11% chance.

Mode 3 - new process, product or service from using the technical content of the TSP, $22,600 to $31,100 net benefit, 1% chance.

The expected net benefit per TSP request is about $850, but three out of five requests produce net benefits of $100 or less. The largest contributing factor to net benefits from the Program is Mode 2 applications. They occur relatively often with modest economic benefits from the TSP information content, so the aggregate economic results are far more important than Mode 3 applications, particularly new products. Successful efforts to develop new products from TSP's have occurred but they are exceptions.

The Tech Brief/TSP Program clearly provides an effective delivery mechanism for selected technology developed by NASA's mission-oriented R&D programs. The combination of a relatively low cost to the Agency, a large group of potential users, and modest net benefits per TSP transaction creates a very good economic return from the public investment. The benefit-to-cost ratio is much better than ratios reported for several other selective dissemination of information systems, primarily due to benefits from applications of the technical content of documents disseminated (i.e., technology transfer as compared to information services).

The evaluation results were derived in a statistical form that can be readily used by TU management in making decisions about Program changes and measuring the effect of those decisions. Several observations and recommendations in this regard are presented in the study report to indicate how Program costs might be reduced and user benefits increased.

It is very important to note that this cost benefit evaluation is based on measuring economic growth increments due to transfer/utilization program activity. This implies that technology transfer is a means to an end--economic growth is the primary objective and transfer is a method for achieving it. Previous transfer/utilization program evaluation methods have measured, for example, program output (e.g., number of Tech Briefs published) or the success rate for transfer efforts. Programmatic changes designed to improve performance for either of these measures can lead to a reduction in the cost benefit evaluation result. Increasing the program output may increase the percentage of irrelvant information in the transfer channel and, therefore, decrease the recipient's chances for identifying useful material. Increasing the transfer rate arbitrarily may lead to duplication of initial adaptation costs by recipients competing in the same market. By measuring program performance in terms of economic growth generated by the investment in program costs, valid comparisons of the effectiveness for different transfer mechanisms may become possible.

INTRODUCTION

The NASA Technology Utilization Program was initiated in 1963 to implement the new technology reporting and dissemination requirements of the 1958 Space Act. The Tech Brief Program was the first operational component of the dissemination effort which now includes Industrial Application Centers, COSMIC, Application Teams, application engineering projects and other technology transfer mechanisms such as conferences, special publications, and technical assistance for potential users of NASA technology.

Document requests and transfer activity due to the Tech Brief Program have been closely monitored since 1968. The transfer data bank, maintained for the Technology Utilization Office (TUO) by the Transfer Research and Impact Studies (TRIS) Project, provides one of the most thorough records of empirical data available for a technology transfer program. A cost benefit study for this data bank was requested by NASA management for two purposes:

- evaluate the overall Tech Brief Program performance in terms of costs and benefits; and
- develop a methodology that could be used in evaluating and improving other Technology Utilization Office programs.

Studies of costs and benefits vary in their definitions and methods due to different purposes for such studies. The present study was conducted to estimate actual costs and benefits resulting from an existing program in order to evaluate past program performance and identify potential opportunities for improvement. Therefore, a Cost Benefit Evaluation (CBE) methodology was specified for the study.

A distinction is made here between CBE and Cost Benefit Analysis (CBA). The latter is generally used to select one of several alternative programs for future implementation. The definitions and methods used in "after the fact" studies (CBE), as opposed to "before the fact" studies (CBA), differ substantially; however, a fundamental requirement for the analytical methods in either case is that a CBA ratio, based on perfect knowledge before the fact, should equal a CBE ratio, based on perfect measurements of costs and benefits after the fact. Furthermore, the benefit-to-cost ratio for program operations over a fixed time period should be the same regardless of whether the study is conducted before or after that time period. In practice, the reliability of data will change over time, but this may be treated as a second order effect in the analytical methods used in CBA or CBE studies.

Section I of this report describes the functions and cost elements of the Tech Brief Program, as well as three basic perspectives that provided the context for defining the net benefits which were measured for the Program. Section II describes the study methodology. Section III presents the evaluation results for the Tech Brief Program, and Section IV presents observations and recommendations. Four Appendices provide: details for the TRIS Data Bank (Appendix A); study methodology and data (Appendix B); data collection tools (Appendix C); and Bibliography (Appendix D).

SECTION I. THE TECH BRIEF PROGRAM

More than 6,000 different Tech Briefs were published by NASA between 1963 and mid-1976 to announce a selected portion (less than one percent) of the technical documents generated by or for the Agency. The new technology disseminated through this mechanism spanned nine subject areas, and included NASA technical advances ranging from hand tools to diagnostic systems to management techniques to materials data. The current Tech Brief distribution list contains over 23,000 names representing every major Standard Industrial Classification (SIC) group. Approximately 1,000 recipients are redistributors, such as libraries and trade journals. Between 1968 and mid-1976, 120,000 requests for documents, or Technical Support Packages (TSP's), announced by Tech Briefs or reannounced by other media were recorded in the TRIS Data Bank. A description of the Data Bank and aggregate data for TSP requesters is given in Appendix A.

Normally, requesters are not charged for Tech Briefs or TSP's, and the NASA Technology Utilization Office (TUO), conducts an active promotional effort to increase the number of subscribers. A new quarterly journal format, NASA Tech Briefs, was introduced in 1976 as part of this marketing effort. Further marketing efforts, using feedback from current users, are designed to promote the diffusion of successful applications for NASA technology.

Thus, the program can be characterized as a well-established Selective Dissemination of Information (SDI) system which provides a diverse, growing audience with free access to an equally diverse collection of technological innovations. This section presents an analysis of program costs and defines the economic measure for program benefits.

Tech Brief Program Costs

The NASA costs for Tech Brief Program operations from 1971 to mid-1976 were collected and analyzed by the TUO Program Control and Evaluation Division. Standard unit costing procedures for information systems, similar to those developed by the Aslib Research Department (Robertson, et al., 1970), were used for the NASA costs.

This program is only one component of the NASA TU Publications Program, which also announces TSP's through TU Compilations and Small Business Administration publications. There is some overlap between the TSP's announced by Tech Briefs and by the other mechanisms. Since program costs could not be separated in some functional areas, the reported costs for the Tech Brief Program include costs for the others. The corresponding TSP requests generated by mechanisms other than Tech Briefs are not currently in the Data Bank, so there is a marginal inconsistency, biased toward a conservative estimate, between the cost base and the benefit base.

Functional elements of the Tech Brief Program are: (1) review and evaluation of the new technology that has been reported; (2) preparation of one-page Tech Briefs that describe the technology; (3) Tech Brief printing and distribution; (4) response to inquiries and TSP requests; and (5) cash awards to innovators. Figure I-1 shows how these elements are related in the publication production process.

New Technology Reporting and Publication System

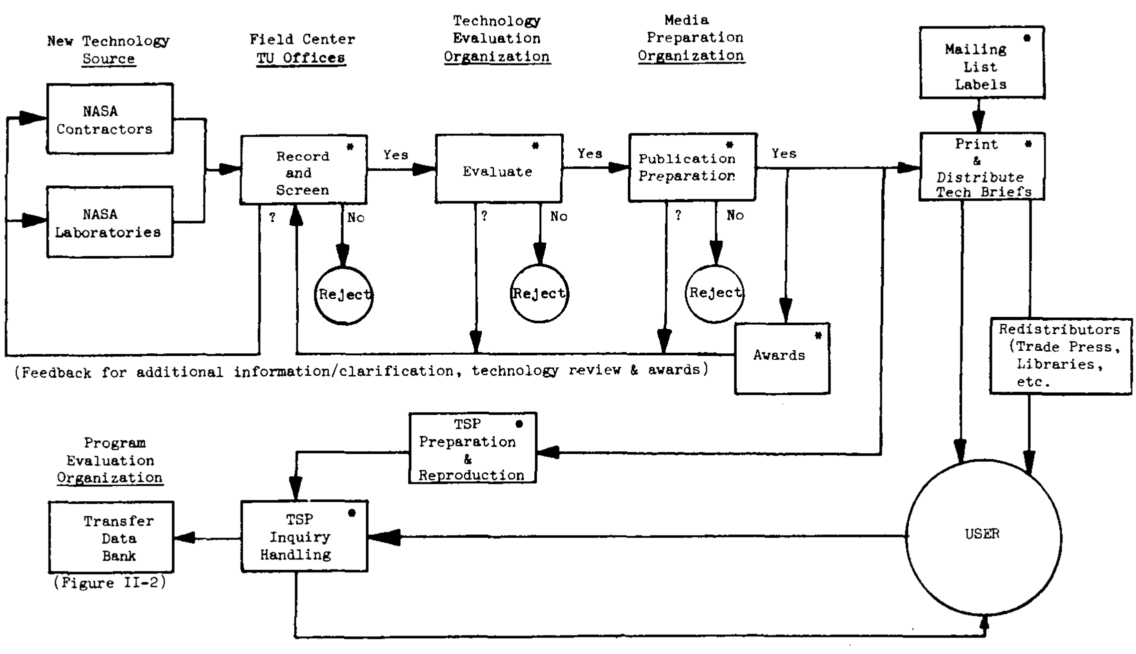


Figure I-1

• Tech Brief Program cost factors

Unit costs were estimated for all program activities, which start when new technology is reported and do not include the cost of developing the technology itself. After listing the activities under each program function, the cost associated with producing a Tech Brief or responding to a TSP request was calculated on the basis of: (1) estimated time and labor rate for governmental employees involved in each activity; (2) the allocated portion of contractor costs; (3) reproduction and mailing costs; and (4) cash awards to innovators.

Table I-1 shows the total costs (unit cost x number of units) for each program function in the years 1971 to mid-1976. The dollars have been converted to 1976 dollars using the GNP Implicit Price Deflator. The unit costs for Tech Brief production and TSP inquiry handling are shown in Table I-2. Unit production costs were higher than usual in 1974 and 1975 when the number of Tech Briefs produced was less than the production capacity. The handling cost for total TSP requests indicates that cost reductions have occurred due to continued increases in efficiency and program experience. The increased efficiency is apparently due to the increasing use of Reader Service Cards for ordering TSP's and operating experience has facilitated the development of several standard response procedures. The remainder of this section describes three perspectives used to select the economic measure for program benefits.

TABLE I-1. TECH BRIEF PROGRAM COSTS BY FUNCTION*
(in thousands of dollars)

	YEAR						
FUNCTION	1971	1972	1973	1974	1975	1976**	TOTALS
1-Screening & Evaluation	394	467	386	395	323	197	2,162
2-Publication & Preparation	173	462	320	186	270	209	1,620
3-Printing & Distribution	49	72	103	58	64	45	391
4-Inquiry Handling	103	138	80	60	60	34	475
5-Awards	32	37	29	30	32	26	186
TOTALS	$751	$1,176	$918	$729	$749	$511	$4,834
Total annual costs discounted at 10% to 1976 value	$1,209	$1,717	$1,221	$882	$824	$511	$6,364

TABLE I-2. ANNUAL UNIT COSTS OF TECH BRIEF PROGRAM*

	YEAR					
UNIT COST	1971	1972	1973	1974	1975	1976**
Tech Brief Production Cost	$1,200	$1,400	$1,600	$2,200	$2,000	$1,600
TSP Inquiry Handling Cost	$2.00	$2.03	$1.98	$1.94	$1.82	$1.66
Tech Briefs Produced	536	756	528	301	339	296

*Converted to 1976 dollars using GNP Implicit Price Deflator
**First 6 months only

Tech Brief Program Benefits Measure

A study of costs and benefits for the Tech Brief Program requires the specification of an economic measure for benefits attributed to the program functions described in the previous subsection. There are two important factors to consider in specifying such a measure:

- the unit of analysis to be used for program results; and
- the economic data to be used in measuring benefits for these units.

At the outset of this study, several unit of analysis options were considered. For example, the unit could have been based on one of three populations: (1) published Tech Briefs (6,000); (2) Tech Brief mailing list in early 1976 (18,000); or (3) individual TSP requests (120,000). At the same time, the corresponding economic measure of benefits for these units could have been specified as: (1) the total cost savings from all applications for an average TSP; (2) how much the average person on the mailing list saves by using the program to acquire technical documents; (3) how much the average TSP requester would have been willing to pay for the document(s); or (4) the costs and benefits attributable to an average TSP transaction. These options did not represent all of the possible units or measures for those units, nor did they uniquely determine which basic approach to use in obtaining the specified data (e.g., indirectly through aggregate economic data or directly through individual estimates). The decision to use individual TSP requests as the unit and the costs and benefits attributable to an average TSP transaction as the economic measure is discussed below.

In order to evaluate the Tech Brief Program, it is important to understand first the larger environment in which this technology transfer mechanism operates. The selection of an appropriate unit, economic benefit measure, and basic measurement method was based on a review of the various perspectives from which the Tech Brief Program performance can be assessed, namely:

(a) How much economic effect is attributable to Federal R&D results (e.g., NASA technology) which the Tech Brief disseminates?

(b) How well does the Tech Brief perform as a delivery system for Scientific and Technical Information?

(c) How well does the Tech Brief perform as a transfer mechanism within a formal Technology Transfer Program?

Figure I-2 indicates the fact that these three perspectives are interrelated. The remainder of this section will briefly describe the overall context for each of these issues and how they relate to the measurement criteria used in the study.

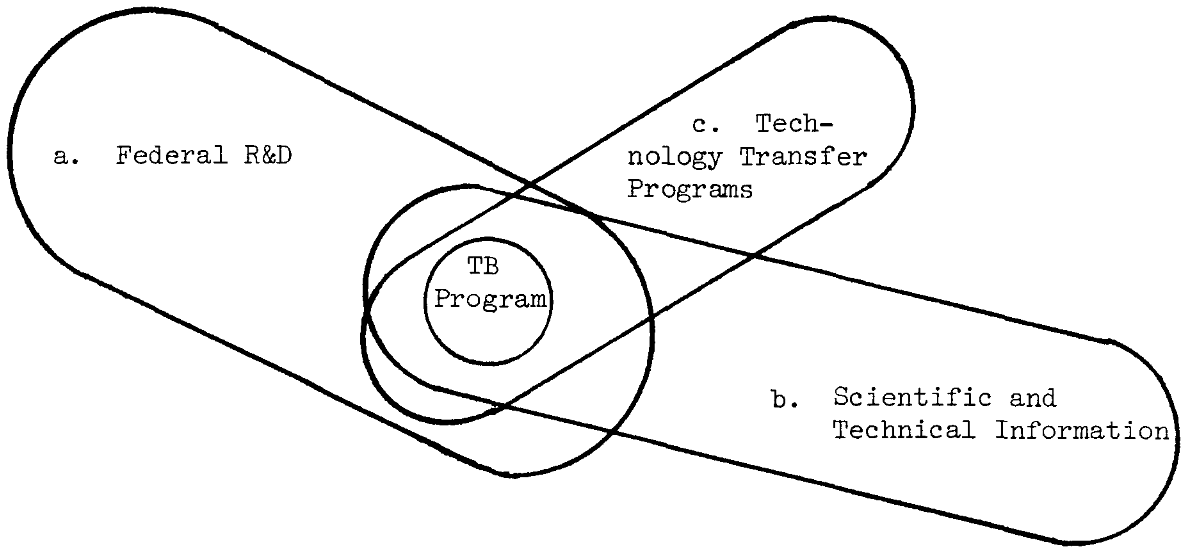
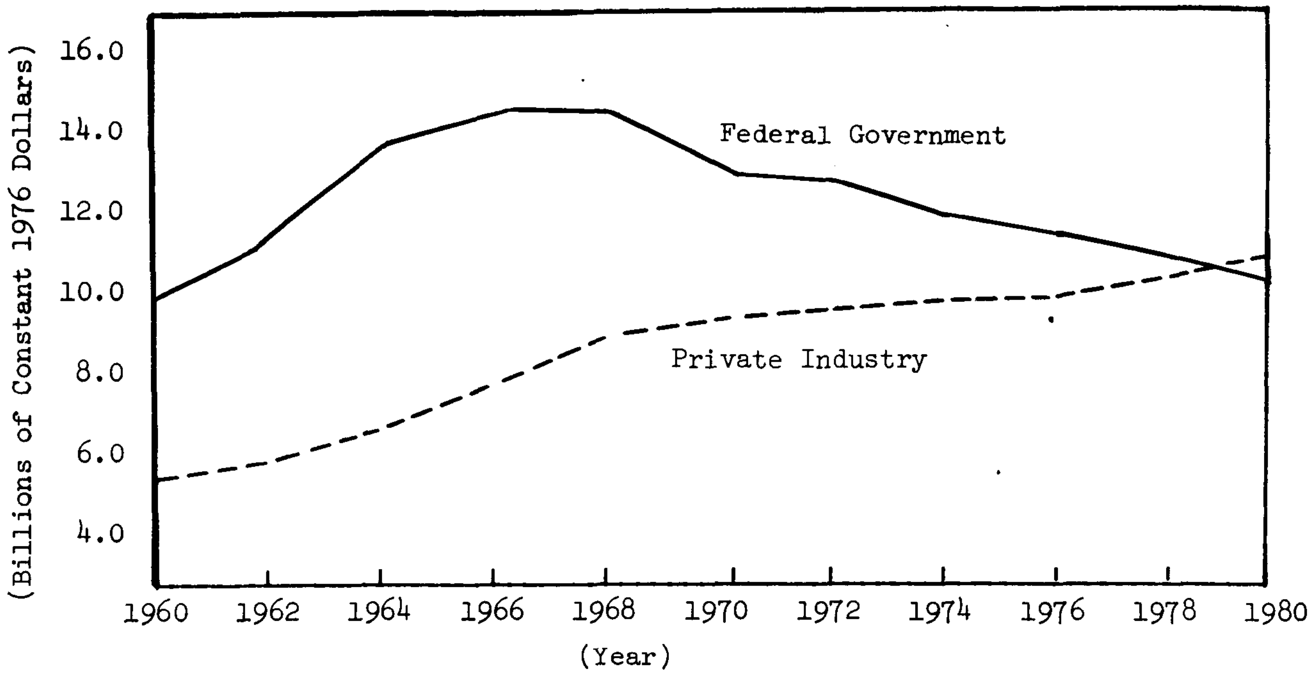


Figure I-2. Three Perspectives for Measuring Tech Brief Program Performance

Federal R&D and the Economy. Economists generally agree that R&D activity has a significant stimulating effect on economic growth. Before R&D activity can produce that effect, however, the advances in knowledge from R&D activity must be applied. Edward F. Denison has estimated that 34 percent of the U.S. economic growth between 1948 and 1969 was due to applications of advances in knowledge (Denison, 1974). He also noted that a major challenge in economic growth research is the development of techniques for acquiring detailed data on the growth effects from various types and sources of advances in knowledge. A fundamental question regarding the source of R&D funding, which loosely corresponds to advances in knowledge, is how much economic growth is achieved through public funds.

In 1975, private R&D investment by U.S. companies amounted to $15.1 billion and federal funding was $20 billion, of which $9 billion went to private contractors (Business Week, June 28, 1976). Figure I-3 shows R&D investment, by source, for the time period 1960-1980.



Source: NSF, National Patterns of R&D Resources.

Figure I-3. Source of Funds for Research and Development 1960-1968

The relationship between these formal expenditures and the production of new knowledge is not well established. An agency's advances in management techniques or equipment maintenance, for example, may be used in achieving economic growth although they may not have come from the agency's formal R&D activity. Similarly, a reinvention of the wheel by an R&D project may not advance the knowledge of wheels. Private firms also develop technical innovations independently of formal R&D funding (Hildred, 1974). The term "R&D results" is used here in its broadest sense to mean advances in scientific or technical capability, including management or maintenance methods, without regard to whether the funding was designated as R&D.

Another issue related to the measurement of economic growth concerns the size of growth increments that can be detected with the measurement method. Growth due to incremental advances in technology may be too diffuse to observe even when measurement and analysis is at the level of individual companies. Nathan Rosenberg concluded that much of the technological change which takes place in an advanced industrial economy is an almost invisible accretion of incremental improvements (Rosenberg, 1975). The magnitude of the cumulative effect is not well documented, but the available data indicate that this source of economic growth may be more significant than major technological changes (Hollander, 1965 and Enos, 1958). This suggests that the measurement method used for federally funded R&D results should be sensitive to very small growth increments--the "fine structure" of economic growth.

A primary economic question for federal agencies is how much effect their advances in knowledge have on economic growth, regardless of whether economic growth is the direct purpose of the agency's R&D activity. Previous technology transfer research by DRI indicates that this question might best be approached by first delineating how the agency's R&D results are transferred to potential users (Kottenstette, et al., 1973). The eight principal transfer modes identified through this research are described in Table I-3. Segmenting the transfer activity in this way provides a framework for characterizing groups that receive technology as well as the types of technology, applications, and economic benefits that each group obtains from NASA-funded R&D.

TABLE I-3. EIGHT TRANSFER MODES FOR NASA-DEVELOPED TECHNOLOGY

MODE	DESCRIPTION
I	Diversification by firms producing for mission-oriented programs through (a) shifts in production facilities and personnel to commercial product lines, or (b) implementation of formal organizational policies to apply mission-related expertise in commercial product development projects.
II	The general improvement of industrial production practice and product quality through agency-initiated specifications and standards for mission hardware procurement.
III	Development of new process and product technology by industrial contractors to promote the direct interests of programs, with subsequent commercial production occurring because other markets and applications are recognized.
IV	Professional activities, including professional design code development, by researchers involved with basic and applied R&D programs in support of mission requirements.
V	Relocation of skilled individuals from mission-related employment to employment in other economic sectors, resulting in the application of acquired skills to solve analogous problems encountered in the new sectors.
VI	Formal agency programs that disseminate, and in some cases adapt, mission-generated technology to organizations in other economic sectors.
VII	Direct access to mission-related scientific and technical information systems by other organizations as part of their normal information acquisition efforts.
VIII	Interagency projects that adapt a first agency's mission-oriented technology to the needs of a second agency or its sector organization.

The performance measure of interest for the Tech Brief Program, as a Mode VI transfer mechanism, is the economic benefit attributed to the technology it has delivered to an audience. The unit of analysis selected for this study was individual TSP requests, rather than TSP requesters, and the characteristic net economic benefit from a TSP request as determined by estimates from a random sample of requesters, was selected as the basic economic performance measure. The incremental benefits most often associated with TSP applications can be measured in this way, rather than by surveying organizations that request TSP's. It is important to note that "economic benefit attributed to. . ." is not quite the same as "economic growth due to. . .," however, it is probably the best approximation available from the average TSP requester. Since the typical TSP user estimate is based on input measures such as person-hours saved, the approximation is reasonably good.

In order to have a standard definition for the economic benefits that can be attributed to federally funded R&D results, the definitions of cost and benefit for federal resource development projects were selected as the criteria for allowable economic estimates (Federal Register, September 10, 1973). In general, costs and benefits are allowable if they are directly due to the Tech Brief Program and would not have occurred without the Program. For example, an estimated portion of increased sales would not be allowable, but a portion of the increase in before tax profit could be.

Two further measurement requirements in the context of Federal R&D and the economy are: (1) the time distribution of TSP requester costs and benefits to provide a net benefit stream for discounting to 1976 value and (2) a description of the type of economic growth increment achieved (e.g., improve an existing process or develop a new service) to provide a better understanding of the growth process associated with TSP's. The measurement issues related to the fact that TSP's provide information, as opposed to tangible goods, are described in the context of scientific and technical information (STI).

Scientific and Technical Information. The Tech Brief Program is a delivery system. In other words, it delivers to potential users documents that contain technological contributions from NASA R&D activity, and thus has a dual role with respect to scientific and technical information (STI)--delivery service and technical content. This dual role presents a basic measurement problem for the economic benefit attributed to TSP information.

If the same technology was also produced by, and available from, other R&D funding sources, then the only allowable benefits would be time savings in comparison to other delivery systems and benefits due to using the technical content should not be allowed. However, an individual may not have access to the same technology from other sources; in which case his/her benefits due to the technology would not have occurred without the Tech Brief Program. For this study, a decision was made to use an empirical approach by asking TSP requesters whether they believed the same information was available from other sources. This decision was based on the fact that individuals choose which technology to implement from the technical alternatives available to them, not from the total alternatives available in the world.

The issue of what to measure as the value of information is widely discussed, without consensus, in the literature (Cooper, 1973; Swanson, 1975; Hindle and Raper, 1976). Quantities proposed or used for studies of information costs and benefits include: what the recipient would be willing to pay for the information (Herring, et al., 1973); time spent in acquiring or assimilating information (Anderson, 1976); the change in expected value from an action due to the fact that information reduced the uncertainty of the outcome (Emery, 1967; Howard, 1966); and time saved in literature review due to the availability of an abstract service (Magson, 1973; Nightingale, 1973). Kenneth Boulding observed that, while information services are priced and marketed, no unit of information exists and it is not property in any ordinary sense, so there are basic difficulties in considering it as a market commodity (Boulding, 1966). In addition, he also notes that knowledge can affect society only through its impact on decisions.

The definition of an economic measure for the value of information should be based on two important ways that technical information contributes to economic growth. By describing the results of experience in how to do something, information can: (1) decrease the cost of deciding which of the available technical alternatives will produce the greatest net economic benefit from implementation; or (2) increase the net economic benefit from a decision by increasing the number of decision alternatives. It is not clear that investments of time or money to acquire information are valid measures of its value in the context above since the expected rate of return on this type of investment is not known. The major unknown factor is due to uncertainty about the utility of a document before an investment is made to acquire it. Until more data are available to calibrate standard economic models (e.g., willingness to pay), the closest approximation to the value of information in a document appears to be a statistical aggregate of individual estimates for the difference in net economic value from an activity with and without the information.

The importance of this issue is indicated by the fact that STI is one of the major products of federally funded R&D activity. The federal obligation for STI in FY 1974 exceeded $400 million, or about 2.5 percent of all federal R&D obligations (Congressional Research Service, 1975). Figure I-4 indicates STI expenditures, by activity, for the time period 1960-1980.

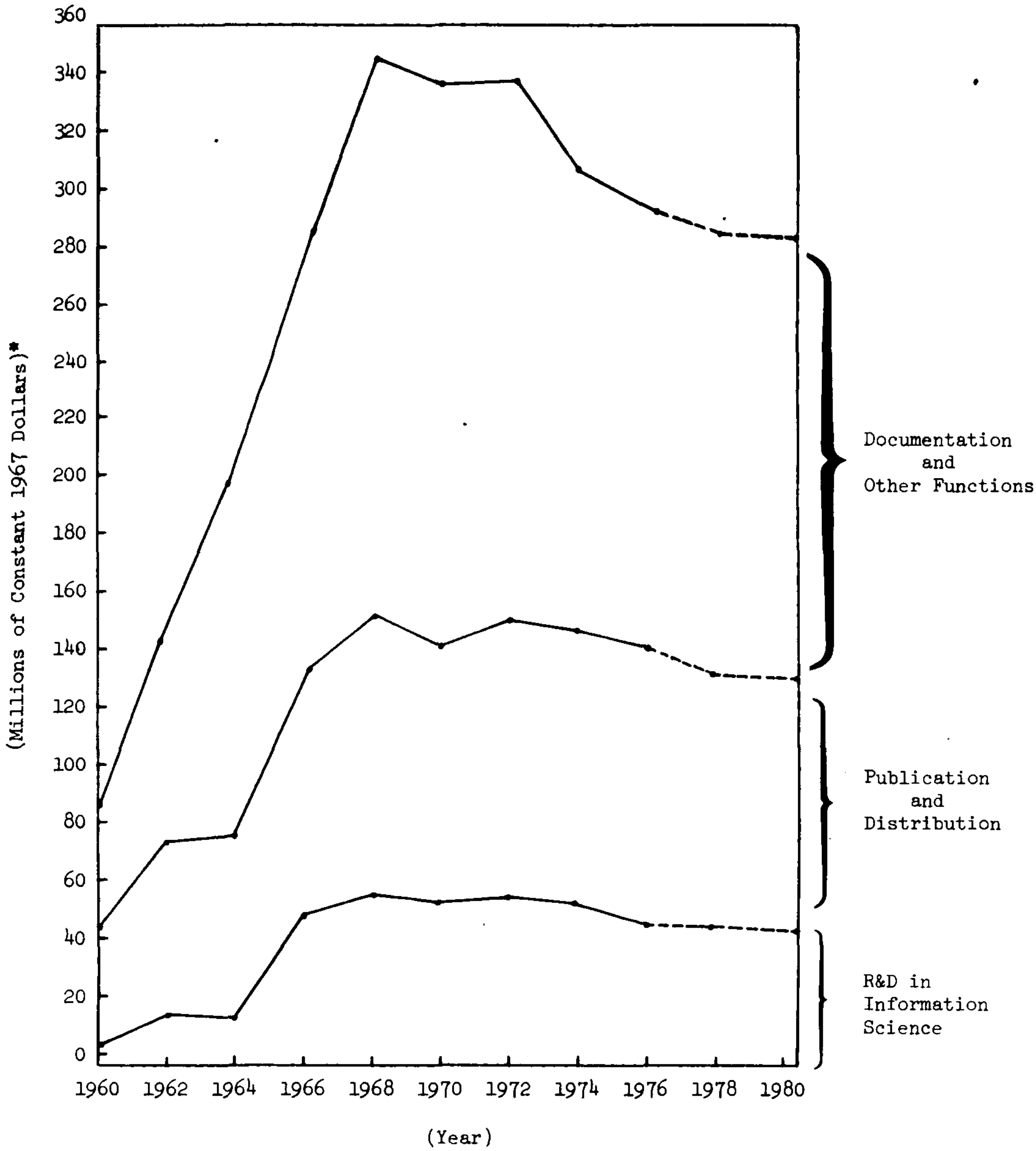


Figure I-4. Federal Obligations for Scientific and Technical Information: 1960-1980

*Using GNP Implicit Price Deflator (1975-1980 NPA)
Source: Market Facts, Inc., Center for Quantitative Sciences (Reported in King, 1976, p. 85)

After reviewing the various approaches to measuring STI benefits, the definition of the benefit measure was further refined. Benefits attributed to the content of a TSP were not allowable if the TSP recipient believed he/she could have obtained the same information elsewhere. In this case the only allowable benefit was the value of time saved by the Tech Brief delivery service. Economic benefits attributed to the technical content of the TSP were allowable if the recipient did not believe the same information was available elsewhere and the benefit estimate was based on the difference in economic value for an activity with and without the TSP information.

In conjunction with the estimated economic benefit from a TSP transaction, each respondent was asked to give his/her method for obtaining the estimate (e.g., how were time savings achieved) and whether TSP information had helped to reduce uncertainty in decision making. These responses may provide a better understanding of the relationship between measured benefits and value of information content for TSP's.

The technological content of a TSP was developed for NASA missions, rather than user needs, so its utility as information is mainly determined after it has been requested and, often, after time (i.e., cost) has been invested in reading and assimilation. Thus, the delivery service has an inherent risk to the user, even if there is no charge by NASA. An important secondary objective in collecting data for the Tech Brief Program was to improve the understanding of how such risks relate to its performance both as an STI delivery system and as a transfer mechanism for R&D results.

Federal Technology Transfer Programs. The third, and final, perspective for assessing Tech Brief Program performance is that of a transfer mechanism for NASA technology. The national interest in technology transfer and utilization has grown rapidly in response to the perceived need to increase efficiency in technological change. The terms "transfer" and "utilization" are distinguished in this study from the term "information dissemination"; the distinction is based on the two different objectives--application of the technology as compared to simply increasing the distribution of knowledge.

Questions concerning the economic effect of federally funded R&D and how to facilitate the utilization of R&D results are emerging as evaluation criteria for the allocation of R&D funds. Table I-4 shows the relationship between R&D budget and transfer/utilization budget for 12 Federal agencies. The annual Tech Brief Program cost of about one million dollars represents 18 percent of the NASA TUO budget and 3 percent of the total nonagricultural technology transfer/research utilization budgets for 11 Federal agencies.

TABLE I-4. SELECTED AGENCY BUDGETS FOR R&D TRANSFER/UTILIZATION, FY 1975

AGENCY	R&D BUDGET (FY 1975, EST., IN MILLIONS)	TT/RU BUDGET* (FY 1975, EST., IN MILLIONS)	TT/RU AS PROPORTIONS OF R&D, IN %
USDA	$ 428	$200.00	47
FHWA	17	3.30	19.4
LEAA	33	4.50	13.6
NIE	55	5.50	10
NSF	83	8.00**	9.6
DOL	15	0.50	3.3
NIMH	93	1.80	1.9
HUD	58	0.35	0.6
EPA	287	1.30	0.45
NASA	3,327	5.50***	0.17
NBS	100	0.10	0.1
AEC (ERDA)	712	0.50***	0.07
TOTAL	$5,208	$231.35	4.4

* Includes program funds only for formally designated transfer/utilization activities. Does not include internal resources, training, informal activities, demonstrations, and the direct support of R&D performers.

** Research Applied to National Needs (RANN) only.
*** Technological spin-off only.
Source: Office of R&D Assessment, NSF, 1975

The National Science Foundation reviewed formal agency programs for the Federal Council for Science and Technology Committee on Domestic Technology Transfer (NSF, 1975). Many of the 25 agencies surveyed reported that the evaluation of their program effectiveness was the weakest part of the program. Among the effectiveness measures in use are: impact measure, such as increases in farm labor productivity; commercialization of R&D results; extent of utilization; user feedback; and number of requests for information. The NSF report concluded:

> "Ideally, transfer/utilization program effectiveness should be based on objective measures of the utilization of program output by the user community, and on the impact utilization has on the attainment of user goals. At present valid, quantitative measures of transfer/utilization program effectiveness do not exist that meet these criteria and permit comparisons across programs. It is not surprising, therefore, to note that less than half the transfer/utilization programs surveyed said they conducted formal surveys of the extent of utilization of their outputs, and that only two said they used 'impact' measures to determine program accomplishments.
>
> . . .
>
> Improvement of Federal technology transfer and research utilization efforts requires that valid, reliable measures of effectiveness be determined. Ideally, such measures should be based on data obtained from users themselves and from systematic observation of user communities. However, since monitoring user behavior can be very expensive, the utility of indirect measures of effectiveness such as the existence of mechanisms for assuring frequent and intensive user involvement should be explored. Thus, the development of feasible and valid measures of transfer/utilization program effectiveness takes on high priority if improved understanding of Federal technology transfer and research utilization efforts is desired."

This Cost Benefit Evaluation of NASA's Tech Brief Program provided an important opportunity for the Agency to help develop transfer/utilization program measurement methods by addressing three questions: (1) How should standardized unit costing procedures be applied to information-based transfer mechanisms? (2) How much does program evaluation cost? and (3) Can statistical methods provide good estimates of how much net benefit is expected per transaction for a transfer mechanism?

Program costs were defined earlier in Section I as all direct and indirect costs to perform program functions (i.e., all activities <u>after</u> new technology has been developed and reported). Standard unit costing procedures not only provided a cost base for use in this study, they also provided a useful measure of production efficiency for program functions.

Program evaluation costs were not included as program operating costs because evaluation is not a direct program function. The annual contractor cost to maintain a data bank and survey TSP requesters by mail questionnaire is about $25,000, or less than three percent of the annual operating cost of the program. The present study required approximately $40,000 in total contractor costs and approximately $7,500 in NASA labor costs. While evaluation costs can vary considerably according to the evaluation objectives, these figures may contribute to a better understanding of the expense required to monitor user activity. Higher costs can be expected when a program monitoring effort is initiated and when program evaluation is done without an ongoing monitoring effort. By maintaining a data bank since 1968, TUO management has achieved efficiencies in meeting its long-term operational and evaluation objectives.

The study methodology (see Section II) was designed, in part, to collect data for estimating the user costs and gross benefits that could be expected for a TSP transaction chosen at random. Since these quantities are extremely variable, data were also collected to clarify the relationships among TSP content, applications, and user net benefits so that the study results might provide some insights regarding potential improvements in the Tech Brief Program.

It is very important to note that this CBE methodology is based on measuring economic growth increments due to transfer/utilization program activity. This implies that technology transfer is a means to an end--economic growth is the primary objective and transfer is a method for achieving it. Previous transfer/utilization program evaluation methods have measured, for example, program output (e.g., number of Tech Briefs published) or the success rate for transfer efforts (cf., Doctors, 1971). Programmatic changes designed to improve performance for either of these measures can lead to a reduction in the CBE measurement. Increasing the program output may increase the percentage of irrelevant information in the transfer channel and, therefore, decrease the recipient's chances for identifying useful material. Increasing the transfer rate arbitrarily may lead to duplication of initial adaptation costs by recipients competing in the same market. By measuring program performance in terms of economic growth generated by the investment in program costs, valid comparisons of the effectiveness for different transfer mechanisms may become possible.

Summary

The economic measure for Tech Brief Program benefits was selected for this study to provide a reasonable approximation to accepted measures in three contexts: economic growth from Federal R&D results; STI benefits and costs; and technology transfer program performance evaluation.

The unit of analysis and the benefit measure were specified in the following way:

- TSP transactions were the units to be analyzed; and

- Estimates (by TSP recipients) of allowable net benefit streams attributed directly to specific TSP transactions provided the benefits measure for these units.

The cost of collecting benefits data increases for TSP transactions further in the past; therefore, the time period from 1971 to mid-1976 was selected to evaluate Program costs and benefits. It should be noted that the net benefit streams estimated for some TSP transactions which occurred in this time period continue into the future and therefore these future benefit values are included in the total benefits calculations.

The study methodology, described in Section II, was designed to: (a) obtain a random sample of these estimates; (b) derive an expected net benefit value per TSP request; (c) extrapolate to the total population of TSP transactions that occurred between 1971 and mid-1976; and (d) calculate the ratio of total net benefits to NASA costs for Tech Brief Program operations during that same period.

SECTION II. STUDY METHODOLOGY

The economic measure and unit of analysis were specified in the previous section. This section describes the methodology for applying the measure to TSP requests and for analyzing the resulting data to derive an expected net benefit value per TSP transaction. Further details on the methodology and data obtained are presented in Appendix B.

Measurement Methodology

As one of the Nation's largest technology transfer programs between an agency and a nonaligned (e.g., nonaerospace user community) the NASA Tech Brief Program generates a great variety of technical documents, applications, and benefits for an equally broad variety of users. The distributions for 120,000 TSP requests with respect to transfer variables such as technology type, applications and users are presented in Appendix A. Since the population is not normally distributed with respect to any variable and most of the variables are not ordered (i.e., computer technology is neither greater than nor less than life sciences technology), the usual statistical calculations such as mean, standard deviation, and correlation coefficients provide little information about the population.

Previous research by TRIS indicates that the distributions of TSP requester responses for transfer variables and benefits are far more relevant and amenable to survey methods. These distributions can then be used to derive an expected value for the variable. This approach is illustrated by a simple example. Suppose, in a game of chance, a person is given the following distribution of chances to win or lose money: 50 percent chance of losing \$1; 40 percent chance of winning \$1; and 10 percent chance of winning \$2. The expected value from the game is: -\$1 times 50% + \$1 times 40% + \$2 times 10%, or $(-1)(.5)+(1)(.4)+(2)(.1)=\$.10$. The numbers .5, .4, and .1 are the probabilities that the various amounts will be won or lost.

The measurement methodology was designed to provide estimates of three basic distributions: total TSP requests distributed over two benefit strata; probability distribution for four application modes from a TSP request in each stratum; and probability distribution for net benefit values in each mode. Figure II-1 presents a flow diagram of the entire study methodology. The next five subsections describe the specific components of the methodology:

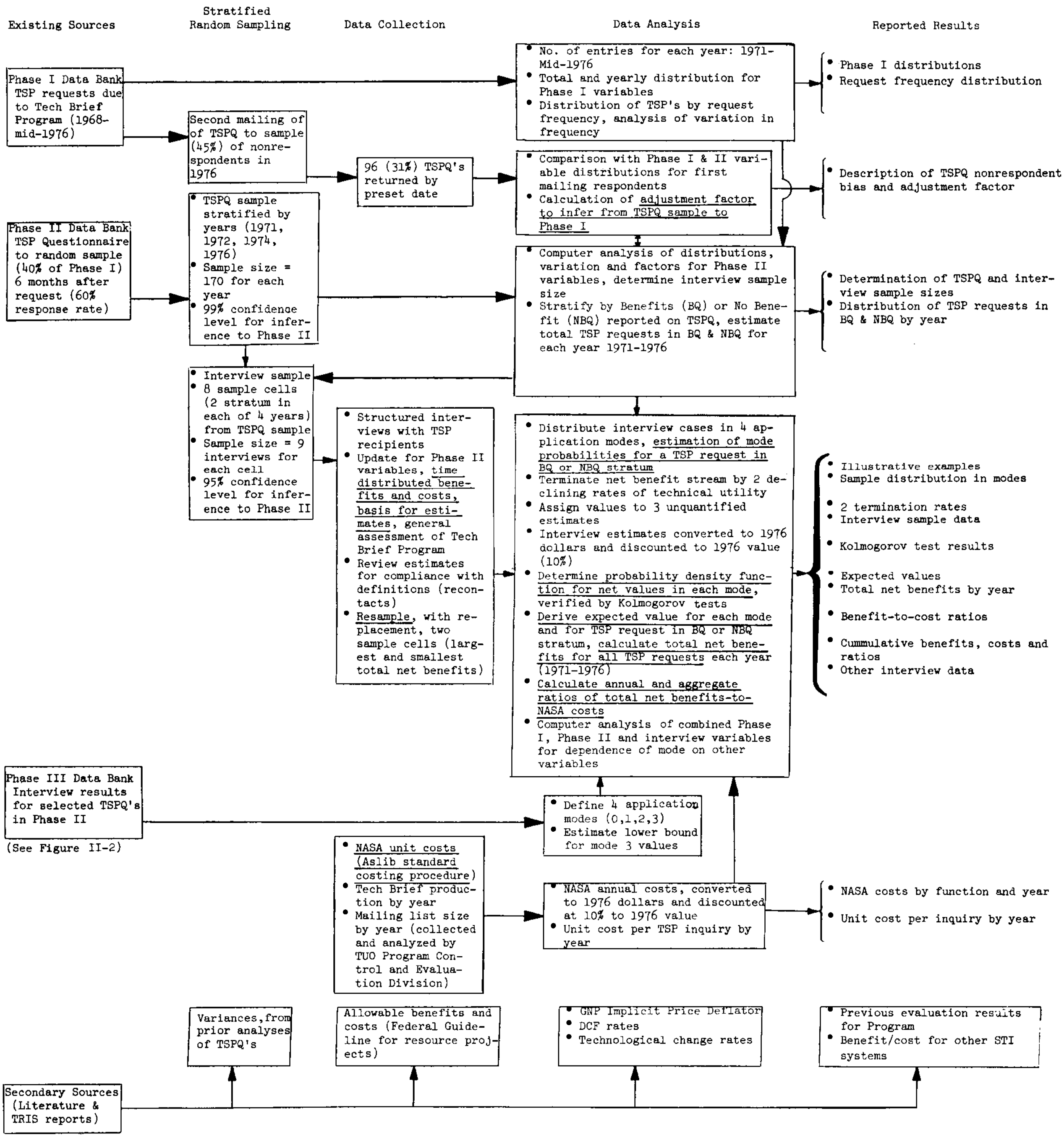


Figure II-1. Study Methodology

- Existing data sources were reviewed and used to the fullest extent possible;

- Random sample selection was designed as a two-tiered process to start with available data;

- Data collection was through in-depth telephone interviews with a random sample of TSP recipients (n = 90);

- Data pre-analysis included four procedures to standardize the economic data; and

- Data analysis included the estimation of statistical distributions and net benefit values.

Existing Data Sources

The availability of TSP requester data from existing sources was an important factor in the decision to conduct a detailed cost benefit study. Therefore, a basic requirement in designing a sampling method for the study was to maximize the use of existing data consistent with standard random sampling criteria.

Figure II-2 presents a flow diagram for the Data Bank which is described more fully in Appendix A. Two key questions were involved in selecting which Data Bank components to use--the time period to be considered and the bias, if any, in drawing conclusions about all TSP requesters in Phase I based on Phase II data.

The time period selected for the study was from 1971 through mid-1976, primarily due to the fact that interviewing costs increase substantially for pre-1971 TSP requests and the data quality decreases. Phase II data for the years 1973 and 1975 in this time period were not selected for sampling because the year to year variations are small enough to justify interpolation from data for adjacent years. In addition, the mail questionnaire (TSPQ) was revised in 1971 so the Phase II data used in the study are not completely homogeneous. (Appendix C contains a sample of each TSPQ for comparison.) In particular, the TSPQ question concerning benefits was less specific in the earlier questionnaire, which increased the proportion of respondents who reported that benefits were realized within six months after receiving the TSP. This difference did not affect the data for any year other than 1971.

The high sampling rate for the ongoing routine mail survey of TSP requests (40 percent of all TSP requests selected at random) is sufficient to draw general conclusions about the entire population of

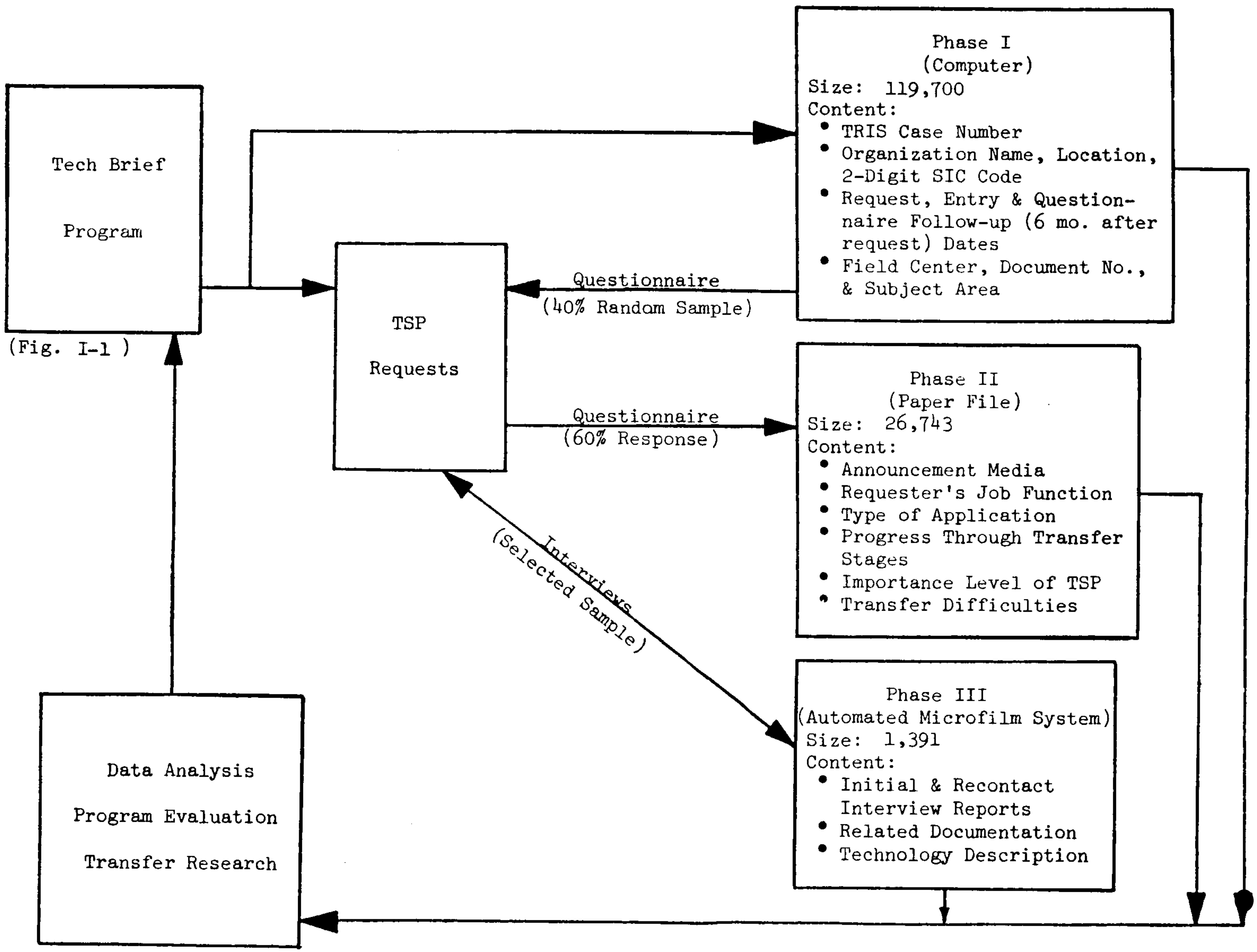


Figure II-2. Data Bank for Technical Support Package Requests: 1968 to mid-1976.

TSP requests in Phase I. However, the TSPQ response rate (60 percent of those mailed out) introduces a potential bias in drawing general conclusions about Phase I from Phase II data. A 1969 survey of nonrespondents to the questionnaire concluded that there were no substantial differences between respondents and nonrespondents (Browne, et al., 1968). Since this question had not been reinvestigated in more than six years, another survey of nonrespondents was included in the current study. The results of the new survey were required for one conclusion about Phase I--whether or not the proportion of benefit responses on Phase II questionnaires would be the same for all TSP requests.

After the Data Bank components were selected and the critical inference issue was identified, a random sampling frame was developed.

Random Sample Selection

The objective in a random sample selection was to specify a sample frame and size sufficient for inferences from the sample results to the population of TSP requests at the 95 percent confidence level. The following Data Bank classes should be distinguished: TSP requests entered in the Data Bank each year; TSP requesters who receive questionnaires; and TSP requesters who return questionnaires.

A second mailing of the TSPQ was conducted for a random sample of about 300 nonrespondents in 1976 to determine whether or not they differed from other respondents and, if so, to determine an adjustment factor for the TSPQ sample results before inferring that those results also hold for the population of TSP requests. This step was very important in the study, since only returned questionnaires would be sampled for telephone interviewing.

The sampling frame was based on stratifying returned questionnaires according to the Data Bank entry year for the TSP request. As described in the previous subsection, the years 1971, 1972, 1974 and January-June 1976 were selected for sampling. Figure II-3 shows the entire sampling frame.

The same TSPQ sample size was used for each year. The standard formula was used in determining the sample size:

$$n = 2\sigma^2 \ (c/2z)^{-2}$$

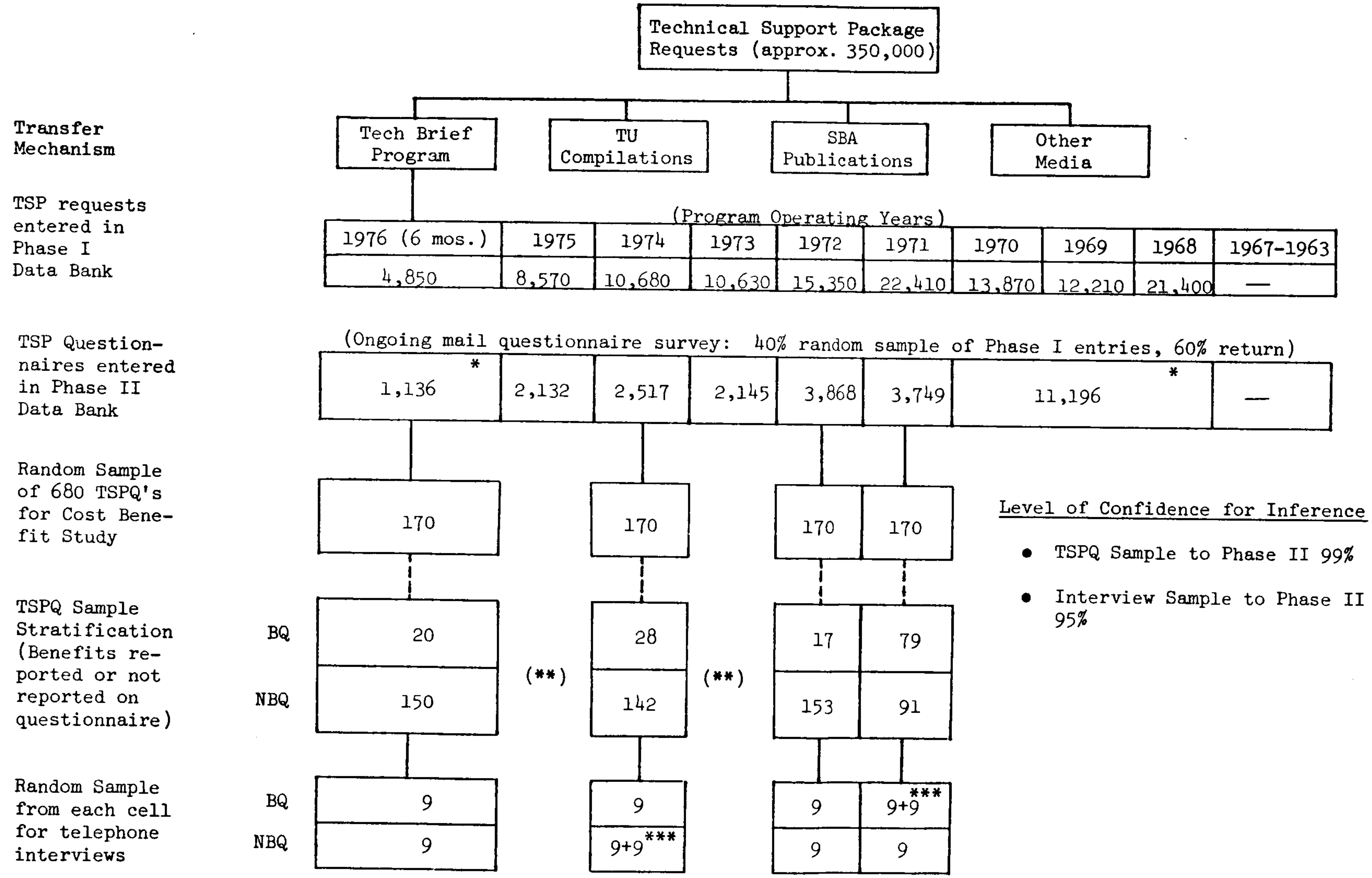


Figure II-3. Random Sampling Frame for TSP Requests.

* Random sample surveys of nonrespondents to TSP Questionnaires.
** Weighted average of adjacent years was used to interpolate proportions for BQ and NBQ strata.
*** Two cells with the most extreme results were resampled with replacement.

where n = sample size (170 as calculated by the formula)

σ^2 = deviance expected in each sample; based on previous TRIS results, the number .895 was used.

c = precision level which was selected to be 0.5.

z = standard normal deviate which is 2.576 for a 99 percent confidence level.

A "systematic drawing with random start" technique was used to select 170 TSPQ's for each of the four years to be sampled. Every k^{th} questionnaire was selected from the case number listing (a unique case number is assigned to each request when it is entered in the Data Bank). A different value of k was used for each year so that adequate coverage would be achieved in each year, although the number of TSPQ's per year varied greatly.

Data from the 680 TSPQ's were then coded for computer analysis and selection of the telephone interview samples. The TSPQ sample for each year was stratified into two groups labeled as:

- BQ for those which reported benefits; and
- NBQ for those which did not report benefits.

In this manner, eight TSPQ sample cells were created for the selection of a telephone interview sample from each cell.

For the purpose of determining the interview sample size, the BQ questionnaires from 1972, 1974, and 1976 were grouped together, and the NBQ questionnaires for these same years were also grouped. The 1971 sample was not included in the analysis for this step due to the change in questionnaires described in the previous subsection. The standard formula, without the factor 2 used above, was applied again to determine an interview sample size from each of the BQ and NBQ groups. The previous values for c and z were used so that the level of confidence for inferring from the interview sample data would be 99 percent for the TSPQ sample, and 95 percent for the Phase II Data Bank. The value for σ, the standard deviation, was determined from TSPQ sample data for 1972, 1974, and 1976 by the following analytic sequence: (1) perform a factor analysis on the questionnaire data to identify which variables accounted for most of the variance in the benefits variable; (2) calculate the variance for each of the variables identified; and (3) let σ equal the largest calculated deviance (1.616) to insure that all responses are adequately represented with regard to benefits. The size n = 27 was thereby determined for each of the groups (BQ and NBQ). Since TSPQ samples from three years were used in this analysis, 27 was divided by 3 to select a sample size of n = 9 which was then used for each of the eight sample cells.

Eight interview samples were then selected for the eight TSPQ sample cells by the same random drawing technique used above. Thus, eight sequences of case numbers were selected for the telephone interview samples and interviews were conducted in sequence for each sample cell. The first nine completed interviews made up the final sample for each cell. An interview was counted as complete if the TSP recipient was contacted. It was counted as incomplete only if the recipient could not be located after making every reasonable effort (including Personnel Departments, forwarding addresses, and all similar leads to current location). Note that the definition of a completed interview is independent of any application for the TSP, or whether the recipient could even remember the TSP. Sixty-nine percent of the attempted interviews were completed, with a range from 53 percent to 100 percent per cell.

The interview sample deviations, for the questionnaire variables most related to benefits, were no greater than the deviations used above in selecting the sample size.

Data Collection

Part of the data needed in this study was already available through the returned TSPQ's, and these data were sampled according to the procedures described in the previous subsection. The major data collection task concerned the eight interview samples, also described above. Copies of the TSPQ's and the telephone interview guide designed specifically for this cost benefit study are in Appendix C.

The critical factors in conducting the interviews were: (1) controlling the interview assignments; (2) determining whether or not the interviewee's estimates were allowable according to the benefit and cost criteria; (3) obtaining quantified estimates from at least 75 percent of the interviews (including $0 estimates); and (4) obtaining the time distribution for estimated values (the net benefit stream) including both actual values in the past and expected values in the future.

The interviews were conducted by three experienced interviewers, but the procedure for assigning interviews from the random sample list was controlled by another member of the research staff. This was done to assure that the interviews were made in the random sample sequence, that no further interviews were attempted for a cell after nine had been completed, and that each interviewer completed at least two of the interviews in the final sample of nine for each cell. The last requirement was to minimize the potential bias due to the interviewers themselves.

Regular meetings were held by the study team to review the interviewee estimates for allowability and to discuss alternative approaches for obtaining quantified estimates in specific cases where data were not provided in the intital interview. If an estimate was not clearly allowable based on the interview notes, a recontact was made to resolve any questions raised by the study team. More than a dozen recontacts were made for this purpose and to try alternative approaches for quantifying estimates.

Based on previous interviewing experience, quantified estimates were expected for most of the costs and about 50 percent of the benefits. The goal for this study was to have more than 75 percent of the estimates quantified. The interviewee's ability to estimate costs and benefits from new technology has increased in recent years, probably due to the increased interest by organizations in detailed cost data for all operational activities. TRIS staff experience, together with the experience of others in TUO programs such as COSMIC and the Industrial Application Centers, indicates that about 40 percent of the respondents can now provide such estimates with little or no probing by the interviewer. This percentage can be increased if the interviewer asks for a sequence of estimates that culminate in the economic estimate. In one interview, for example, the estimated benefit from an increase in safety was obtained by first getting an estimate of how much more time would have been required, using the previous method, to achieve the same level of safety, and then getting an estimate of how much the time saving was worth. As a last resort only, the forced choice approach was used (e.g., which of the following categories best characterizes the benefit: $1-$10, $11-$20, etc.); however, this was rarely used since it provided very little information about how the estimate was determined. Only one of the 90 estimates of costs in the interview sample was unquantified, and 21 of the 90 estimates of benefits (23 percent) were unquantified. The distribution of costs and benefits over time (the net benefit stream) was readily available from each interviewee, even unquantified estimates were identified as to when the cost or benefit occurred, or was expected or occur.

The two cells with the most extreme net benefit results were resampled. A second telephone interview sample was drawn, with replacement, from the TSPQ sample population for the cells with largest (1971 BQ) and smallest (1974 NBQ) net benefit amounts. The second sample for 1971 BQ essentially repeated the first sample results. The second sample for 1974 NBQ essentially repeated the 1971 NBQ, 1972 NBQ and 1976 NBQ results, rather than repeating the first sample results. In each case, the second sample was combined with the first to form samples with n = 18 for all the subsequent analytic steps.

Data Pre-Analysis

Cost and benefit data were obtained by interviewing recipients for the random sample of 90 TSP requests described in the previous subsections. A four-step sequence was required, however, to convert these data into the proper form for direct comparison during analysis. The four steps were:

(1) Convert all data to 1976 dollars;
(2) Assign values to three of the unquantified estimates;
(3) Terminate seven net benefit streams which continued into the indefinite future; and
(4) Discount all net benefit streams to their 1976 value.

Dollar conversion. Step 1 was a straightforward application of the GNP Implicit Price Deflator to the estimates given in dollars other than 1976. The conversion factors were obtained from the June 1976 *Economic Indicators*.

Value assignments. Step 2 was used for the one unquantified cost and two of the 21 unquantified benefits that remained after every effort was made to obtain interviewee estimates. The 90 pairs of cost and benefit estimates were separated into natural groups: zero costs and benefits (26 in group); nonzero costs and zero benefits (one unquantified out of 13 in group); zero costs and nonzero benefits (13 unquantified out of 22 in group); and nonzero costs and nonzero benefits (eight unquantified benefits out of 29 in group). Since the one case with unquantified costs was similar to the rest of the group, the group average cost ($200 in 1976 dollars) was assigned. The last group contained two estimates that the unquantified benefits had exceeded the quantified costs. In each of these two cases, the benefit had occurred in the same year as the cost. The assigned benefit value in each case was equal to 110 percent of the respective cost, so the assigned net benefit was 10 percent of the quantified cost.

The other 19 unquantified benefits were left indeterminate since there was no clear rationale for assuming they were similar to, or some proportion of, the aggregate quantified estimates in the same group. When the quantified data were analyzed however, the various extreme possibilities (e.g., all 19 being equal to 0 or the six with actual costs being equal to those costs) were considered for these 19 unquantified benefits. As shown in the following data analysis subsection, any biases that may occur in the unquantified benefits do not significantly effect the analytic results.

Benefit stream termination. Step 3 was required for net benefit streams which the interviewees described as continuing into the indefinite future. There were seven of these continuing net benefit streams in the sample data. The problem of estimating how long a TSP requester will continue to use information and benefit from the document is difficult and any method for obtaining an answer will introduce some uncertainty in the quantitative results. The method developed for this study is based on a reasonable assumption that, for each recipient, the utility of a technical document will generally decline after reaching a maximum utility. This assumption means that after the maximum use for a document is achieved in the context of the recipient's technological practice, the document contents will gradually become obsolete in that context since technological practice will generally continue to change.

The primary questions in applying this method concern the rate of declining technological utility for each TSP recipient with a continuing net benefit stream and the marginal level of residual utility when the TSP will be discarded. Two different approaches were used to specify declining rates for each of the seven continuing streams: a flat rate of 10 percent in each case and a variable rate (4-9 percent) determined for each case based on the rates of technological change for industrial sectors related to the particular application in the case. The industrial sectors used in the second approach included the application sector as well as the sectors supplying goods used in the application. The variable rate was determined by adding all the application-related rates of technological change; the rates of technological change were obtained from Edwin Mansfield's well-known work on the subject (Mansfield, 1968). The marginal level of residual utility was assumed to be 50 percent for all seven cases, so the standard compound interest formula using various declining rates were set equal to 0.5 and solved to determine how many years should be used in each continuing benefit stream.

The 10 percent rate spanned a six-year period from the initial year of current use. Benefit totals obtained by using this rate are labeled B(10). The variable rate spanned from eight to 17 years for the seven cases, but an upper limit of 12 years was assumed for each TSP since they are paper-bound documents that will undoubtedly become illegible over time. Benefit totals obtained by using the variable rate are labeled B(4-9). Table II-1 shows the rates and years for each continuing stream using the variable rate approach.

TABLE II-1. TERMINATION OF NET BENEFIT STREAMS BY VARIABLE RATES OF DECLINING TECHNOLOGICAL UTILITY FOR TSP'S.

CASE NUMBER	SAMPLE CELL	RELATED RATES OF CHANGE (%)*	DECLINING RATE (%)	YEARS TO REACH 50% RESIDUAL**
15064	1976BQ	3.6 (Electrical Equipment)	4.0	17
97988	1974NBQ	3.2 (Petroleum) 1.0 (Machinery)	5.0	14
97564	1974BQ	3.2 (Petroleum) 3.7 (Chemical)	7.0	10
96748	1974BQ	2.6 (Chemical, disembodied) 3.6 (Electrical Equipment)	7.0	10
97287	1974BQ	8.3 (Instruments)	9.0	8
59126	1971NBQ	3.2 (Petroleum)	4.0	17
59162	1971BQ	8.3 (Instruments)	9.0	8

*Source for rates of technological change: Mansfield, 1968.
**A maximum of 12 years was assumed for TSP's since they are paper-bound documents.

The effect of these two approaches, fixed rate and variable rate, on the benefit and cost data is illustrated by an example which shows the aggregate change they cause in the net benefits. A medical instrument manufacturer, Case Number 59162, used a TSP in 1971 to develop a new production process and substantially accelerated the market introduction of a new product in 1972. The 10 percent rate of declining utility would terminate the company's benefit stream in

1977 with an accumulated net benefit of $32,592. The rate based on technological change is 9 percent (based on the rate for the instrument industry) which would terminate the stream in 1979 with an accumulated net benefit of $47,760. In this case, the difference between terminating in 1977 and 1979 is a 47 percent increase in net benefits even though both termination dates are in the near future. The effect of these two approaches for declining utility rates is somewhat less for the total net benefits from 90 interviews.

The total net benefits from all interviews were analyzed to determine the proportion of projected, as compared to past, benefits for each approach. The projected benefits were defined as the continuing benefit stream portions which are expected to occur in 1978 and beyond. Since the interviews were conducted in late 1976 and the estimates were based on actual benefit streams, the estimates for 1977 appear to be reasonably certain to occur rather than projected expectations. With the 10 percent rate, projected net benefits were 8 percent of the total and the average termination date for seven continuing streams was 1979. With the variable rate, projected net benefits were 26 percent of total net benefits and the average termination date was 1983. This suggests that the 10 percent rate provides a conservative estimate of total benefits from the Tech Brief Program. Statistical analysis in the next subsection indicates that the variable rate may correspond more accurately to economic growth from technological change. Further research is needed for better estimates of the rates and marginal level of residual utility.

Discounted values. Step 4 was a straightforward application of the standard discounting method*, using a rate of 10 percent, for all cost and benefit data. The choice of this procedure, however, is a major issue since it treats benefits in the past as if they were dollars saved at 10 percent interest. This issue and a mathematical derivation of the correct procedure are presented in Appendix B.

The interview data, modified by these four steps, are presented for each sample cell in Tables B-1 through B-10 in Appendix B.

Data Analysis

After the data were in a comparable form, they were statistically analyzed to estimate the expected net benefit value per TSP request. The anlaytic procedure consisted of four steps:

(1) Distribution of TSP requests into two strata (BQ and NBQ);

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*The discount factor for the year T is $(1 + .1)^{1976-T}$

(2) Distribution for each stratum of TSP requests in four application modes;

(3) Distribution for each mode of net benefit values and expected value; and

(4) Combining steps 2 and 3 to estimate the expected value for a TSP request in each stratum.

Strata distribution. The two strata, described in the subsection on sample selection, are based on TSP questionnaire responses where users reported that benefits had occurred (BQ stratum) or had not occurred (NBQ stratum) within six months after receiving the TSP. Every TSP request is represented by either the BQ or the NBQ interview sample cells so the key inference from the study data to the total TSP request population (Phase I Data Bank) concerns the distribution of all requests in these two stratum (i.e., how many requests are represented by the BQ sample cells and the remainder must be represented by the NBQ sample cells). This distribution was based on the TSP questionnaire sample distribution and the results of a nonrespondents survey, a second mailing of the same questionnaire, conducted as part of the current study.

The rate of "apathetic" responses (e.g., missing data or "don't know") on questionnaires from the second mailing was twice the rate for these responses on questionnaires returned from the original mailing. This result indicates that the Phase II Data Bank, which was sampled for this study, probably contains a higher proportion of BQ responses than would be the case if all questionnaires were returned. Therefore, the TSP questionnaire sample proportion in the BQ stratum for each sample year was reduced by an adjustment factor of .86 to obtain an estimate of the total TSP requests (Phase I Data Bank) in this stratum for the same year.

The adjustment factor was based on the fact that apathetic responses increased by a factor of two and on the results from nonrespondent studies reported in the literature (Lansing and Morgan, 1971). It was determined as follows: the initial 40 percent sample was randomly selected, so the 60 percent response represents 60 percent of the Phase I population; half of the remainder are probably no different from this 60 percent, so 80 percent of Phase I has the same proportion in BQ as the questionnaire sample; half of the remaining 20 percent probably has half this proportion; half of the remaining 10 percent probably has one-fourth of this proportion; and the last 5 percent probably has none of this proportion (i.e., (.8) (1) + (.1) (.5) + (.05) (.25) + (.05) (0) = .86). Table II-2 shows the adjusted distribution for TSP requests, by year, in the BQ and NBQ strata.

TABLE II-2. TOTAL TSP REQUESTS REPRESENTED BY BQ AND NBQ STRATUM

Year	TSP Requests Recorded	Reported Benefits in TSPQ Sample No. (% for n=170)	Estimated % of Requests Represented by BQ Cells (Non-respondent factor= .86)	TSP Requests Represented by BQ Cells	TSP Requests Represented by NBQ Cells
1976 (Jan.-June)	4,850	20 (12%)	10%	485	4,365
1975	8,570	---*	13%	1,114	7,456
1974	10,680	28 (16.5%)	14%	1,495	9,185
1973	10,630	---*	11%	1,169	9,461
1972	15,350	17 (10%)	8.5%	1,305	14,045
1971	22,410	79 (46.5%)**	40%	8,964	13,446
		...	...		
Totals	72,490			14,532 (20%)	57,958 (80%)

*Not sampled, values interpolated from adjacent years.
**TSP Questionnaire changed, the previous benefit question was more broadly stated.

Application mode distribution. Four application modes provide an important basis for relating the type of TSP application to the magnitude of net benefits attributed to the document. They are defined by the application context used in estimating costs and benefits, but this definition is not based on the magnitude of these estimates.

- Mode 0 - no application was, or will be, attempted and there are no costs or benefits;
- Mode 1 - costs and benefits are attributed to acquiring information from a source;
- Mode 2 - costs and benefits are attributed to applying the TSP content to improve existing products, processes or services; and
- Mode 3 - costs and benefits are attributed to applying the TSP content to develop new products, processes or services.

The four modes are interpreted in the technological change context. Individuals who are attempting to change technology within an organization may acquire technical information from many sources such as personal contacts, professional or trade publications and TSP's. If the information does not appear to be relevant, it is often discarded before any costs or benefits occur (Mode 0). If it appears to be relevant for a planned change or it provides an opportunity for improvement, time is usually invested to internalize the information. Benefits may be attributed to the information source because it delivered the information and time was saved by not having to find it through other sources. When the cost or benefit estimates are associated only with information acquisition activities, the TSP application is in Mode 1. If the information is perceived as not being available from other sources and the TSP content was incorporated in a change within the organization, the application is in Mode 2 or 3 depending on the type of change. In terms of technological change, the last two modes are usually very different with regard to organizational decision processes, costs, and time required for adoption. For more detailed economic analyses, products and processes would be distinguished as output and input submodes. Most TSP applications in Modes 2 and 3 are for processes, rather than products.

The interview results were grouped according to strata (45 interviews in each) to estimate two distributions over the four application modes. Each distribution was interpreted as the probability that a TSP request in the stratum would be in one or another of the four modes. Table II-3 shows the distribution for each stratum and the weighted average distribution for all TSP requests.

TABLE II-3. PROBABILITY DISTRIBUTIONS FOR APPLICATION MODES

	MODE			
STRATUM	0	1	2	3
BQ	.200	.556	.178	.067
NBQ	.378	.533	.089	.000
WEIGHTED AVERAGE*	.342	.538	.107	.013

*Average for BQ and NBQ strata, weighted by the total number of TSP requests in each stratum given in Table II-2.

The Mode distributions for each of the eight sample cells (four sample years for each stratum) were compared for differences among the strata and years. Note that the probability in Table II-3 for being in Mode 1 is about the same for TSP requests in either the BQ or NBQ strata. However, requests in the NBQ group are twice as likely to be in Mode 0, half as likely to be in Mode 2, and almost never in Mode 3, as compared to the BQ group. This indicates, then, that the TSP requester has a reasonably good idea, after six months, concerning the eventual application of the TSP.

Table B-11 in Appendix B presents more details about these distributions for the four sample years. The interview data were collected and analyzed as samples of the two strata, rather than samples of the yearly requests. This means that averages should be weighted by the stratum proportions (which incorporate 1975 and 1973 requests), rather than the request proportions for the four sample years.

Net benefit distributions. The 90 interview results were next regrouped by application mode to analyze the distribution and expected value of net benefits in each mode. The number of cases in each mode was: 26 in Mode 0; 49 in Mode 1; 12 in Mode 2, and 3 in Mode 3. All of the unquantified results were in Mode 1 so only 30 quantified estimates were available for analysis in that mode. Five of the seven continuing net benefit streams were in Mode 2 and the other two were in Mode 3 so only these modes were affected by the range of values [B(10) and B(4-9)] introduced by the two termination methods described in the Data Pre-Analysis subsection. Note that Mode 0 is simply the single net benefit value of $0.

Graphical methods, including normal probability graphs, were used initially to develop hypotheses regarding which type of standard distribution family characterized the sample data distribution for the other three modes. The results indicated that Mode 1 is normally distributed, Mode 2 is either normal or lognormal, and Mode 3 is probably a lognormal distribution. The lognormal distribution, together with other skewed distributions such as Gamma and Pareto, is commonly used for economic data analyses (Johnson and Kotz, 1970).

The Phase III Data Bank was reviewed in order to estimate the lower bounds for values in the last two modes. Based on 164 TSP-related transfer cases with quantified benefit data, $1,000 was selected as a reasonable lower bound for Mode 3 values. The lower bound for Mode 2 values appears to be one or two engineering days, so $200 was used as a reasonable lower bound. These lower bounds were used to simplify the comparison of Mode 2 and 3 sample distributions to the lognormal distribution since a logarithmic transformation of a lognormal distribution minus its lower bound is a normal distribution.

Two statistical methods were then used to test how well the sample data in each mode fit the standard distributions indicated above. The importance of these tests is due to the key role in the study methodology for the standard distribution forms specified with the test results. The distribution form is the basis for calculating the expected net benefit value from a TSP request in a mode, as well as a model for how economic benefits are obtained from technical information.

The first test was the Lilliefors version of the Kolmogorov test to compare sample distributions with the normal distribution after the variable has been standardized. (A variable is standardized by subtracting the sample mean and dividing by the sample standard deviation.) This test is very sensitive since it compares the differences, at each value in the sample, between the sample accumulative probability and the normal accumulative probability; the test result is the largest absolute value among these differences (Conover, 1972). Some variation in this test result is expected for samples drawn from a distribution which is known to be normal so the result is interpreted by giving the expected proportion of normal samples that would have greater differences than the test result observed for the actual sample. Tables B-12 through 15 in Appendix B show the tests and results for each mode.

The Lilliefors test indicated that:

- Mode 1 values are similar to a normal distribution but there appears to be a cusp near 0 which may be due to the 19 unquantified cases in this mode or to the existence of two exponential distributions rather than one normal distribution.

- Mode 2 values are close to a lognormal distribution, closer than they are to a normal distribution, and the variable rate for declining technological utility gives a better fit than the fixed rate of 10 percent; and

- Mode 3 values are close to a lognormal distribution and the variable rate gives a better fit but the results are not conclusive for a sample of size 3.

The second test was a graphical method, using correlation coefficients, to determine empirically what percentage of 1,000 normal samples had a lower correlation coefficient than the data sample being tested. The sample values, or logarithms of these values minus their lower bounds, were plotted for each mode against standardized normal values in the following way: the i^{th} sample value (for a sample of size n ordered by magnitude) was paired with the standard normal value having an accumulative probability equal to $(i-3/8) \div (n+1/4)$. The correlation coefficient was then calculated for this set of numbers. One thousand samples of size n from a normal distribution were generated by computer and a comparable correlation coefficient was calculated for each sample.

The proportion of normal samples with coefficients smaller than the test sample was thereby determined empirically. Figures B-1 through 4 in Appendix B show the graphs and results from this test.

Table II-4 summarizes all of the test results. The correlation test agreed with the Lilliefors test for Modes 1 and 3, but the distribution for Mode 2 appears to be more complex. The Mode 2 values can be separated into two submodes based on whether the technology is used only by an individual (probably a normal distribution) or the application is institutionalized in the organization (probably a lognormal distribution).

TABLE II-4. TEST SUMMARY FOR NET BENEFIT DISTRIBUTION IN MODES

MODE	SAMPLE SIZE	HYPOTHETICAL DISTRIBUTION	LILLIEFORS TEST		CORRELATION TEST	
			RESULT	INTREPRETATION*	RESULT	INTREPRETATION*
Mode 1	30	Normal	.156	5-10%	.97	
Mode 2						
B(10)	12	Normal	.223	10%	.966	44%
B(4-9)	12	Normal	.166	over 20%	.967	46%
Mode 2						
B(10)	12	Lognormal	.191	over 20%	.948	20%
B(4-9)	12	Lognormal	.149	over 20%	.954	25%
Mode 3						
B(10)	3	Lognormal	.251	**	.929	27%
B(4-9)	3	Lognormal	.326	**	.961	47%

*Test result interpreted as the expected percentage of samples, from the hypothetical distribution, which would give a worse result than was obtained from the sample data; a higher percent indicates a higher likelihood for the hypothetical distribution.
**Test results are ambiguous for sample size of three; some references (e.g., Siegel, 1956) indicate that the interpretation for these results would be over 20 percent.

The distributions selected after the above analysis were: Mode 1 (normal); Mode 2 (lognormal); and Mode 3 (lognormal). While there is some uncertainty regarding the distributions for Modes 1 and 2, the expected value for each mode would not be changed by more than 7 percent if the indicated alternative distributions were used instead. Analysis of the alternative distributions is important, however, in the development of a model for how technical information generates economic benefits. The hypotheses and questions related to this subject are discussed in Section IV.

The expected value for net benefits distributed according to a probability density function, f(x), is:

$$E[f(x)] = \int_{-\infty}^{\infty} xf(x)dx.$$

This can be interpreted as the value expected for the average net benefit per TSP request in a mode if estimates were obtained from every TSP requester in that mode. For standard distributions such as normal or lognormal, the expected value may be calculated from the parameters which appear in the function, f(x), for the distribution. The values used for these parameters were the maximum likelihood estimators derived from the sample mean and standard deviation for each mode. These derivations, together with the expected value formulas, are presented in most mathematical statistics books (c.f., Johnson and Kotz, 1970). Table II-5 shows the expected value in each mode for a TSP request using the two different rates of declining technological utility.

TABLE II-5. EXPECTED NET BENEFIT VALUE PER TSP REQUEST IN MODES *

MODE	EXPECTED VALUE AT 10% RATE, B(10)	EXPECTED VALUE AT VARIABLE RATE, B(4-9)	PROBABILITY
0	$0	$0	.34
1	$100	$100	.54
2	$4,900	$5,000	.11
3	$22,600	$31,100	.01

* Rounded to hundreds of dollars.

Since Mode 1 contained 19 unquantified cases, the available data were further analyzed to determine how much the expected value might change if all 49 cases in the mode were quantified. This analysis was based on calculating the four different means for four groups of 49 undiscounted values. These were obtained by combining the 30 quantified values with the possible extreme situations: all 13 cases with zero costs and unquantified benefits as having one of two extremes (either zero benefits or benefits equal to the average for this group); and all six cases with quantified costs as having one of two extremes (either zero benefits or benefits equal to the costs). The resulting four means were averaged under various reasonable assumptions regarding the relative probabilities for the extreme situations they represented. The resulting averages were all within 10 percent of the mean for the 30 undiscounted values so these values were used, after discounting, to estimate the expected Mode 1 value of $130 (later rounded to $100).

Expected value per TSP request. The final step to estimate the expected net benefit per TSP request was based on the request distribution in modes (see Table II-3) and the expected value from each mode (see Table II-5). The probability distribution for net benefits from a TSP request is given by the sum of probability density functions for each mode, weighted by the probability for being in the four different modes. The expected value for this sum is equal to the weighted sum of expected values in each mode. For example, the expected value from a TSP request in the BQ stratum, for the B(10) values, is:

$$(.200)(\$0) + (.556)(\$100) + (.178)(\$4{,}900) + (.067)(\$22{,}600) = \$2{,}400.$$

Table II-6 shows the expected value for a TSP request in either stratum, together with the average weighted by the aggregate proportions for these two strata. The year to year variations in BQ and NBQ proportions are relatively large so the stratum expected values, rather than the weighted average, were used in calculating the total net benefits due to program operations between 1971 and mid-1976.

TABLE II-6. EXPECTED VALUE PER TSP REQUEST

STRATUM	EXPECTED VALUE* FOR B(10)	EXPECTED VALUE* FOR B(4-9)
BQ	$2,400	$3,000
NBQ	$ 500	$ 500
Weighted Average	$ 900	$1,000

*Rounded to the nearest $100.

The methodology used in this study required more complex statistical analysis than the simple procedure of calculating mean and standard deviation for the 71 quantified net benefits in the sample. The difference between these two methods is illustrated by considering the B(10) net benefit values. The weighted average expected value per TSP request was estimated to be between $800 and $900 based on sample sizes for a 95 percent confidence level. The net benefit mean for B(10) values was: $2,700 with standard deviation (σ) equal to 6,950 for the BQ sample and $800 with standard deviation (σ) equal to 2,250 for the NBQ sample. The 95 percent confidence interval around the mean is $\pm 1.65\ \sigma$, so the strata weighted average net benefit per TSP request would be given as $1,200 $\pm 1.65\ \sigma$ (i.e., between -$4,100 and $6,500). This result contains less information than the result above because large net benefits estimated by a few TSP requesters create a highly skewed, non-normal distribution. The use of normal distributions and statistics is not generally appropriate unless the conceptual model for a population indicates some reason for assuming that a central tendency can be expected for sample data.

Summary

The expected value per TSP request was obtained by analyzing the TSP request sample data to estimate three distributions: requests in two strata; probability for four application modes from a request in either stratum; and net benefit values in each application mode. This methodology provided both a high level of confidence in the result and a statistical model for the ways that technical information generates economic benefits. The significance of this model for understanding, and improving, the aggregate effect from individual technology utilization activities will be examined in the remainder of the report.

The results from this section are used in the next section to estimate total net benefits from the Tech Brief Program between 1971 and mid-1976. Other data from the study samples are also presented in Section III to provide a qualitative evaluation of the Program. The distributions derived in this section are further analyzed in Section IV to identify potential improvements in the Program.

SECTION III. STUDY RESULTS

The primary evaluation result for the Tech Brief Program is the ratio of user net benefits to NASA costs. This ratio was slightly over 10:1 for the total costs and benefits that were measured according to the definitions and methodology presented in Sections I and II. The derivation of this ratio from the results in those two sections is presented below, together with illustrative examples and qualitative evaluation data from the study.

Quantitative Results

Total net benefits were calculated by multiplying the number of TSP requests in two basic strata, BQ and NBQ, for each year (from Table II-2) by the expected net benefit value per request in each stratum (from Table II-6). The use of B(10) and B(4-9) values introduced an expected value range for requests in BQ so the net benefit total also appears as a range. Table III-1 shows the results of this calculation for 1971 through mid-1976, together with the annual Tech Brief Program costs (from Table I-1) and the annual benefit-to-cost ratios. Figure III-1 shows the cumulative benefits and costs for the same time period.

TABLE III-1. ESTIMATED NET BENEFITS, NASA COSTS, AND BENEFIT-TO-COST RATIOS FOR THE TECH BRIEF PROGRAM

(millions of dollars)

	NET BENEFITS*				BENEFIT-TO-COST RATIO
YEAR	BQ STRATUM	NBQ STRATUM	TOTAL	NASA COSTS**	(LOW-HIGH RANGE)
1976 (Jan.-June)	1.16 - 1.46	2.18	3.34 - 3.64	.51	6.5 - 7.1
1975	2.67 - 3.34	3.73	6.40 - 7.07	.82	7.8 - 8.6
1974	3.59 - 4.48	4.59	8.18 - 9.07	.88	9.3 - 10.3
1973	2.81 - 3.51	4.73	7.54 - 8.24	1.22	6.2 - 6.8
1972	3.13 - 3.92	7.02	10.15 - 10.94	1.72	5.9 - 6.4
1971	21.51 - 26.89	6.72	28.23 - 33.61	1.21	23.3 - 27.8
Totals	...	...	63.84 - 72.57	6.36	Aggregate Ratio = 10.0 - 11.4

*Calculated by multiplying the number of requests in each stratum (Table II-2) by the expected net benefit per request in each stratum (Table II-6), the range in values is due to the two methods for terminating net benefit streams.

**From Table I-1

Note: All quantities are in 1976 dollars discounted at 10 percent to their 1976 value.

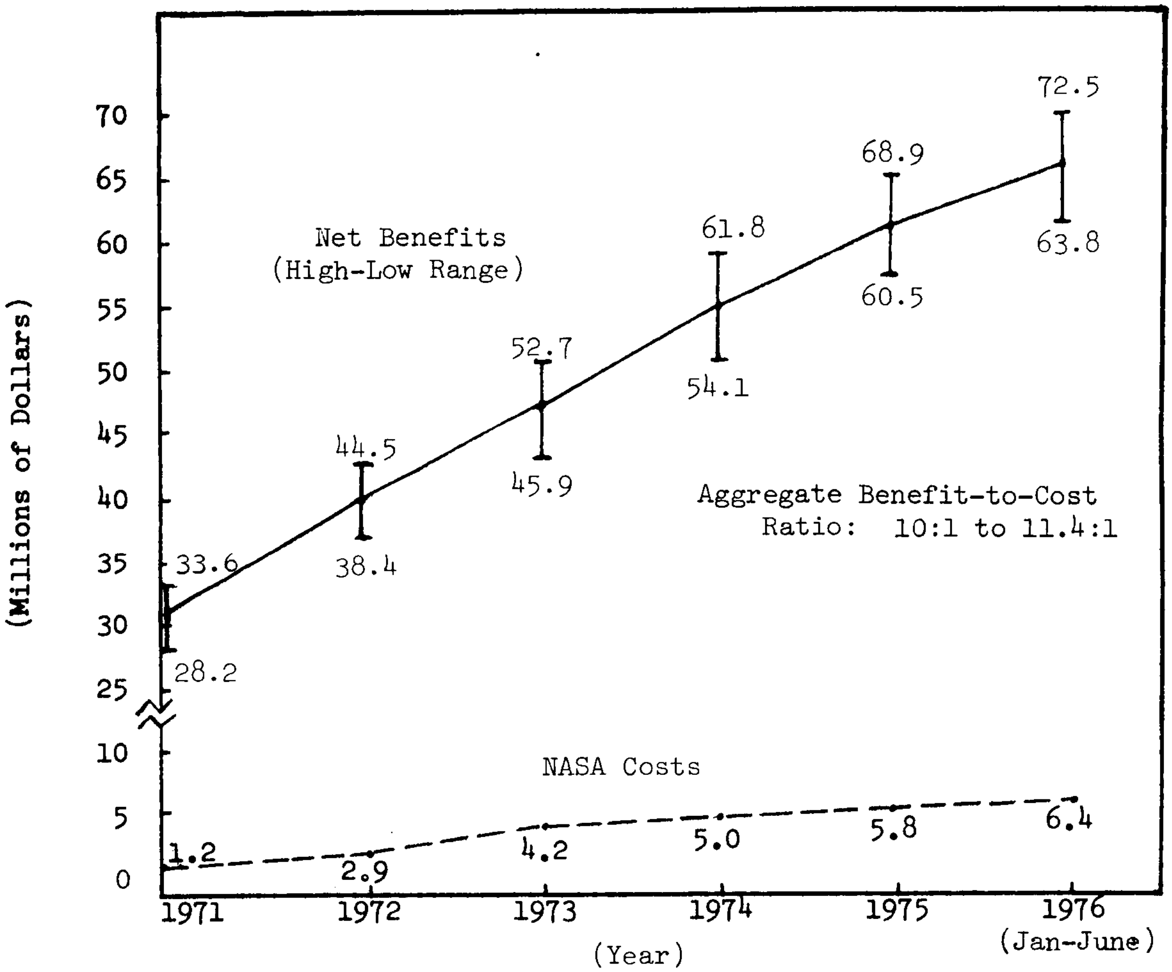


Figure III-1. Cumulative Net Benefits and NASA Costs for the Tech Brief Program Operations From: 1971 to Mid-1976.

The level of confidence in these expected net benefit values is 95 percent based on the sample sizes; however, a more significant reliability test for expected value is whether the results are essentially repeated by additional samples. While this study did not include additional samples, a fairly high degree of similarity was observed for distributions from different sample cells with some exceptions which have a reasonable interpretation (e.g., it is too soon to expect Mode 3 applications from 1976 requests). In addition, qualitative and quantitative data from the study sample were quite similar to previous results for Data Bank samples (e.g., 10 to 12 percent of the TSP requests produce Mode 2 or 3 applications and 1971 was a very good year in terms of useful technical content in TSP's and number of requests). The study results, therefore, are consistent internally, between sample cells, and externally, with other samples from the same Data Bank.

The interpretation for these quantitative results is based on the methods used to derive them. NASA costs were calculated by multiplying estimated unit costs by the number of units, so they represent actual expenditures. Net benefits, on the other hand, were obtained. by calculating the statistical expectation for three probability distributions estimated from random sample data, so they represent the net benefits that would be expected if all TSP requesters were interviewed. Figure III-2 illustrates the probability distribution, over net benefit values, for a TSP request in the BQ stratum.

A ratio of 10:1 compares favorably with ratios obtained in cost benefit studies for other systems that disseminate selected scientific and technical information (STI): 1:1 (Mensch, 1973); 2.7:1 (Magson, 1973); 3.2:1 (Mason, 1972); and 11.8:1 (Nightingale, 1973). It should be noted, however, that these are much smaller systems (typically serving a few hundred people), with benefits due only to cost savings in STI delivery or awareness services (i.e., Mode 1 only). No previous economic studies of systems comparable to the Tech Brief Program were identified during the literature review for this study.

The comparison above is based on only the second of three perspectives (economic growth from R&D, scientific and technical information, and technology transfer) described in Section I. The other two perspectives relate to a significant difference in purpose for government agency programs, such as Tech Briefs, that disseminate selected new technology generated by the agency as compared to most selective dissemination of information (SDI) systems. The latter systems are typically used to reduce the cost of accessing available information, whereas the Tech Brief Program function is to facilitate beneficial secondary uses for the technological content of the documents being disseminated. While there is no standard for comparison, the program performance with respect to this primary function appears to be good since about one out of ten TSP requests produce applications for the technology described in the TSP.

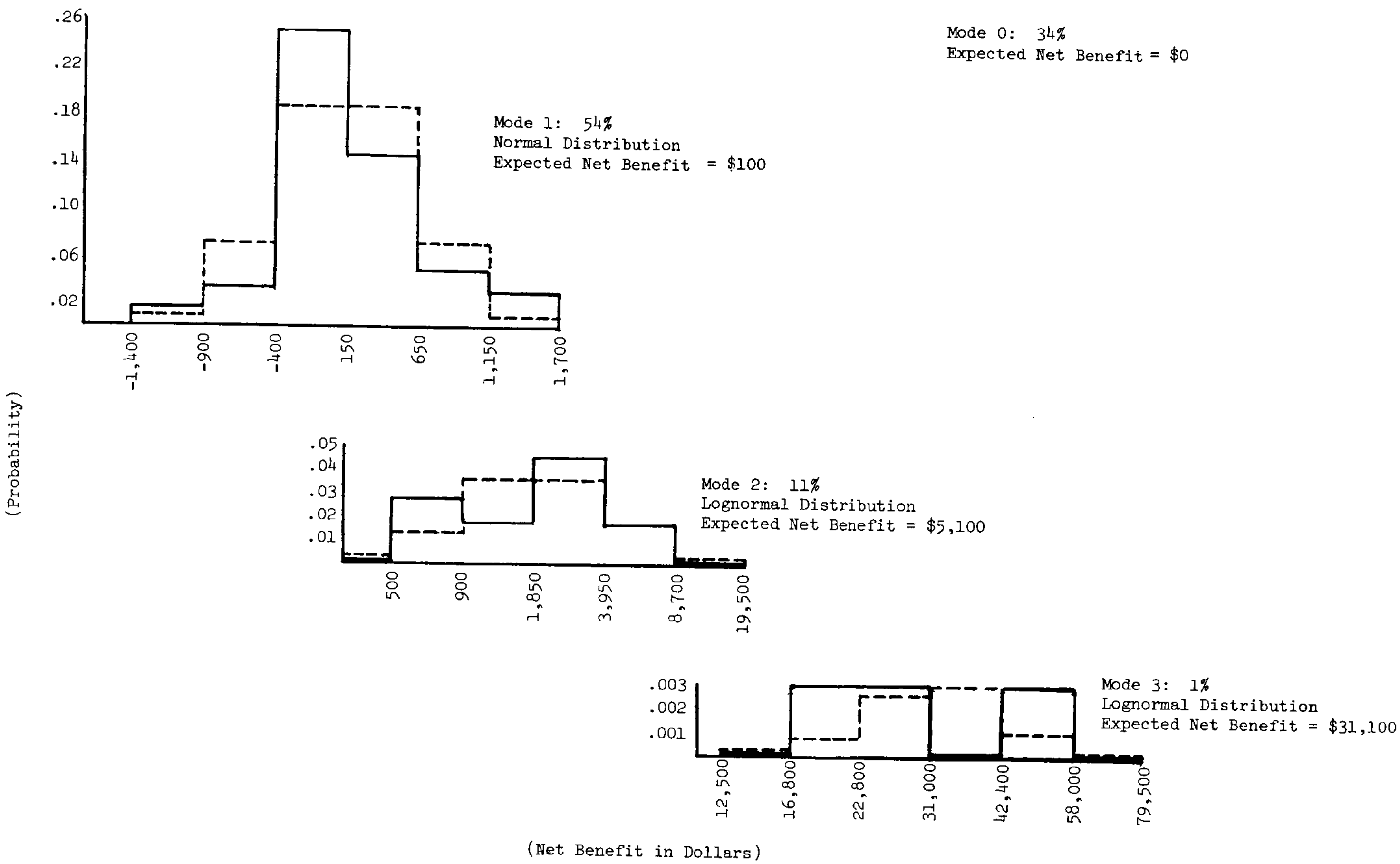


Figure III-2. Theoretical and Actual Probability Distributions for Net Benefits from Each TSP Request*

*Solid lines indicate actual distribution and dashed lines indicate theoretical distribution.

Illustrative Examples

Several examples from the interview sample illustrate TSP applications and estimates in the three nontrivial modes. The estimates are in 1976 dollars and have not been discounted to 1976 values.

Mode 1

- A program manager for a small aerospace firm used information from a TSP on antenna attenuators in preparing a contract proposal (cost estimate = $42 in 1971; benefit estimate based on saving two days of research = $174 in 1971).

- A researcher with a heavy equipment manufacturer avoided R&D costs by using information from a TSP on laser energy in an unsuccessful research project (cost estimate = $5,600 in 1974; benefits in 1974 estimated to exceed cost by an unquantified amount).

Mode 2

- The maintenance engineer for a large nursing home applied information from a TSP describing a fire alarm inspection detector to improve his regular inspection process (cost estimate = $35 in 1976; benefit estimate = $156 per year starting in 1976).

- A research manager with a major oil company uses a biological handbook TSP as a textbook in a program for training engineers to analyze environmental impact of process wastes (cost estimate = negligible $; benefit estimate based on time saved each year = $1,600 in 1972, declining to $160 in 1976 and expected to continue at this annual rate).

- A maintenance engineer with a large municipal wastewater treatment facility uses a lubrication handbook TSP to select equivalent, but cheaper, lubricants than those specified by equipment manufacturers and to reduce his inventory of different lubricants from 60 to 15 (cost estimate = negligible $; benefit estimate based on cost and time savings = $1,120 per year).

Mode 3

- The R&D director for a small medical equipment manufacturer used a TSP that described a specialized wire welding unit to reduce R&D costs for developing a new production process and to accelerate substantially the market introduction of a new product (cost estimate = $3,500 in 1971; benefit estimate = R&D cost reduction of $7,500 in 1971 and a proprietary percent of before tax profits for annual sales since 1972).

The TSP applications documented in the Phase III Data Bank (see Appendix A) indicate that net benefits for both Mode 2 and 3 can reach hundreds of thousands of dollars. For example, a contamination control handbook TSP was used to develop improved procedures recommended in the American Hospital Association handbook. This Mode 2 application started in the early 1970's and the current annual cost savings are estimated to be $250,000 and 2,000 person-hours. The fusion welding workmanship standards described in another TSP were used by a major civil engineering firm to develop acceptable new weld methods and to qualify welders for a dam project. The Mode 3 benefits were estimated to be $250,000 in cost savings on a $50 million project. Benefits of this magnitude are exceptional and would not be expected in a random sample of only 90 TSP requests.

Qualitative Results

The primary data collection objective was economic data, but the qualitative data also provide useful indicators about program performance. Figure III-3 presents data from the interview sample for transfer variables such as stage and importance. The interviewees were also asked about their assessment of the Tech Brief Program as a whole and how they ranked the program as an external source of information. Figure III-4 shows the general assessment. In particular, a significant portion of the sample stated that TSP's provide information that is not generally available elsewhere or that helps reduce uncertainty in making decisions. These two responses were usually associated with Mode 2 and 3 benefits. They indicate a very deliberate approach to information acquisition, in contrast to a more or less random activity that identifies technical opportunities almost accidentally.

Another TRIS study is currently analyzing the TSP request patterns for multiple requesters--those individuals who have ordered dozens, or even hundreds, of TSP's over the years. The preliminary results indicate that a number of individuals routinely use the Tech Brief Program as a channel for acquiring NASA technology which is then redistributed within their organization. In large corporations, for example, the redistribution may be accomplished by entering selected Tech Briefs into the formal, internal dissemination systems such as newsletters or computerized STI systems. In small corporations (and small working groups in larger organizations) the TSP requester often maintains his own filing system for Tech Briefs and TSP's. When a technological need develops, he may assist fellow employees by locating useful technology in his own information system.

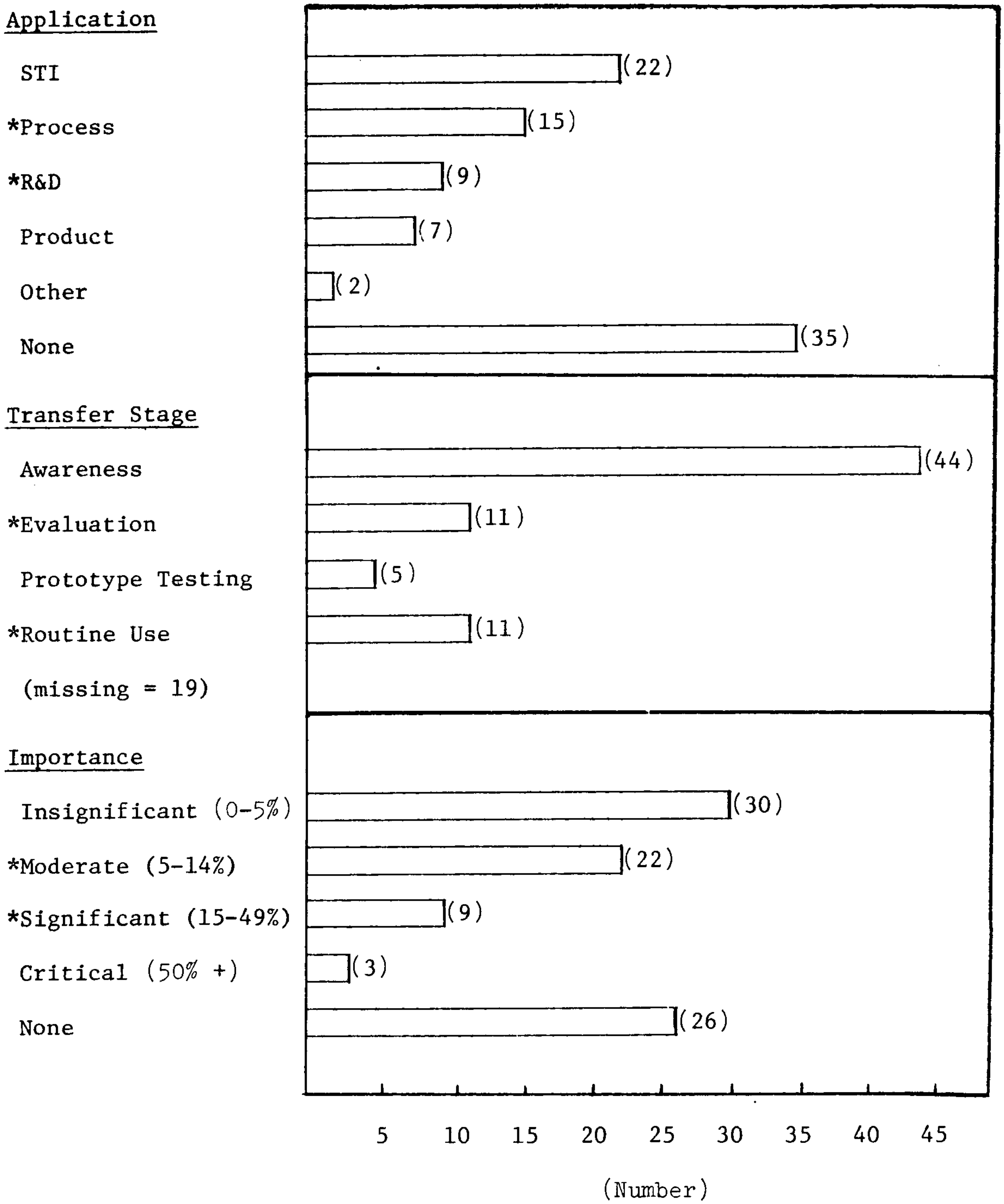


Figure III-3. Application, Transfer Stage and Importance for TSP Requests in Interview Sample.

*Most likely categories for Mode 2 or 3 benefits.

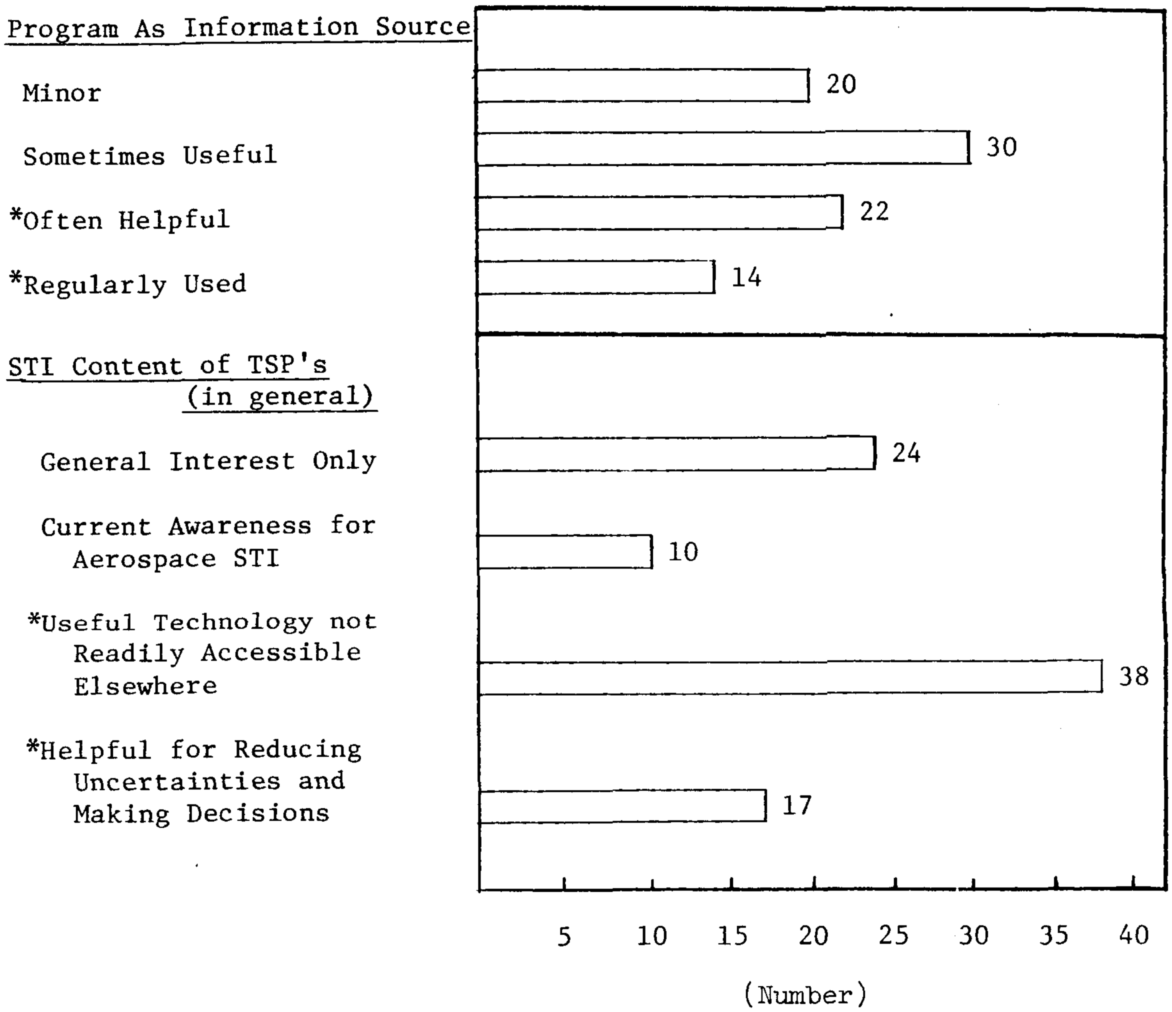


Figure III-4. Tech Brief Program Assessment by Interview Sample.

*Most likely categories for Mode 2 or 3 benefits.

The average time spent by the interview sample in acquiring technical information from outside sources was 22 hours per month, with a range from 0 to 80 hours. The sample acquired, on the average, 8 percent of its outside information from TSP's, with a range from 0 to 51 percent.

The results of a TUO-funded, 1967 DRI study on technology acquisition channels indicated a somewhat lower relative rating for all government publications, including Tech Briefs, than the rating by the current study sample. The 1967 results were based on samples of individuals in four industrial classifications, rather than the Tech Brief mailing list. The average time spent in acquiring information was in the range of 34 to 47 hours per month (Gilmore, et al., 1967). The differences between the two study results suggest that the Tech Brief mailing list population: (1) may spend less time acquiring information (possibly because the individuals are more involved in processes and less involved in product development or R&D than the 1967 study sample); and (2) rates the Tech Brief Program higher as a source of information than the general population of industrial technologists does.

One of the recommendations from the 1967 Channels Study was to increase, if possible, the redistribution of Tech Briefs through acquisition channels ordinarily used by technologists. There are two indications that this has happened to some extent. The Tech Brief mailing list now contains slightly more than 1,000 known redistributors, of which about 30 percent are media such as trade or professional publications, and an unknown number of the informal redistributors described earlier as multiple requesters. Table A-8 in Appendix A shows that the source of awareness for TSP requests was 43 percent due to Tech Briefs directly and 29 percent due to trade or professional publications.

Conclusions

The Tech Brief Program clearly provides an effective delivery mechanism for selected NASA technology. The combination of a relatively low cost to the Agency, a large group of potential users, and modest net benefits per transaction creates a very good economic return for the public investment. The study results imply that a document delivery system is probably the most cost effective way to transfer some, but not all, of NASA's technological advances. In recent years, similar systems have also been initiated by agencies such as the Bureau of Mines, the Energy R&D Administration, and the three Armed Service.

Improved processes, services, or products are developed from the TSP information for almost 11 percent of all requests, and the expected net benefit from a Mode 2 application is approximately $5,000. New processes, services, or products are much less common, about 1 percent of all TSP requests, and the expected net benefit from a Mode 3 application is over $22,000. The largest contributing factor to net benefits from the Program is Mode 2 applications. They occur relatively often with modest economic benefits from the TSP information content, so the aggregate economic results are far more important than Mode 3 applications, particularly new products. Successful efforts to develop new products from TSP's have occurred but they are exceptions. More typically, such attempts lead to a net loss for the TSP requester. Even for successful Mode 3 applications, the TSP information is usually a minor technical input (about 5 percent) to the new economic activity.

These results indicate that patterns of successful technology transfer through the Tech Brief Program might be identified by using the statistical distributions developed with the study methodology. The next section will describe potential uses for such statistics in managing the Program together with potential applications for a similar CBE methodology in other TUO Programs.

SECTION IV. OBSERVATIONS AND RECOMMENDATIONS

The second objective in conducting this study was to develop a practical CBE methodology that could be used to improve the Tech Brief Program and to evaluate other TUO Programs. The results indicate that the study methodology can satisfy this objective for relatively low evaluation costs. In this regard, the guidelines suggested for evaluation management by the Office of Management and Budget are also satisfied, since the evaluation results were derived in a form that can be readily used by TUO management in making decisions about Program changes and measuring the effect of those decisions (Morrison, 1975). This section first presents observations about transfer mechanism selection and TSP pricing, and then makes several recommendations concerning: (1) Tech Brief Program improvements; (2) other applications for the same statistical methodology; and (3) further development of a statistical model.

Observations

Performance measures, such as transfer effectiveness or benefits, for a technology transfer program generally have large variations over the many possible combinations of program parameters (e.g., technology types, transfer mechanisms, and potential user groups). Statistical results from this study indicate that the combinations with the best performance might be identified to provide success characteristics for use in managing the program to improve performance. This information could be used to address TUO management questions such as how to select the most effective transfer mechanism for different types of technology and whether to charge recipients for the services or documents.

It should be noted, however, that only one performance measure should be selected for this purpose. If the benefit-to-cost ratio were selected as the primary measure for the Tech Brief Program, this would imply that economic growth is the main objective for this dissemination activity. Program changes directed toward increasing other performance measures (e.g., widest possible dissemination or cost recovery) might interfere with the benefit-to-cost performance, so the selection of a performance measure is a basic policy question for TUO management. The importance of this policy issue is illustrated in the context of two Program management questions mentioned above: selection of the appropriate transfer mechanism and pricing.

Transfer mechanism selection. The CBE study results agree with previous TRIS research results regarding the types of technology which do, and do not, tend to generate benefits through the Tech Brief transfer mechanism. For example, the Program appears to be most effective for technical information that helps the recipient decide how to solve a problem with existing technological options, rather than information about a new technical option (i.e., information that reduces the uncertainty for a technical decision, rather than information that increases the choices even though the new option may represent an improvement). This represents one important way to classify the technical content for new technology so that the most effective transfer mechanism could be selected for a class of technology.

This classification method is also related to a classification of NASA R&D activities into basic research, applied research, and mission-oriented development objectives (Ault, 1976). The Tech Brief Program appears to be much more effective for new technology from developmental activity (i.e., "how to" technology) that compiles available information in order to help decide among options for operational systems. This indicates a need to select appropriate technology for the Tech Brief transfer mechanism and to be able to specify other transfer mechanisms when the Tech Brief is not appropriate in terms of costs and expected benefits. It may become possible to specify appropriate TUO transfer mechanisms for new technology from each type of R&D activity but the existing mechanisms probably do not now provide enough flexibility for the full range of NASA activity or new technology types.

Pricing. The issue of charging recipients for TSP's or Tech Briefs can be addressed in a new context by using costs and net benefits for the program--How much U.S. tax revenue is generated by the Program expenditures and would this return on the public investment be adversely affected by a policy of immediate cost recovery through pricing? Although the study samples were not specifically designed to answer this question, the NASA cost and net benefit data indicate that the costs are more than recovered in corporate tax revenues alone. The ratio of estimated Federal tax revenues, shown in Table IV-1, to NASA costs is probably between 1.3 and 2.2.

The effect of pricing on TSP requests is indicated by DRI data from 1969 when TSP's were sold for $3 each by the Federal Clearinghouse for Scientific and Technical Information (now the National Technical Information Service). As a result, the monthly TSP requests in 1969 were 600 fewer than the comparable months in 1968 and the percentage of requests by small firms decreased. The latter effect appeared to be due to the purchasing process required for the transaction (Freeman, 1969). Another effect, apparently related to the procurement process, was a major increase in the proportion of TSP requests by librarians, whose TSP selections were more oriented toward reference materials when compared to TSP selections by technical personnel. These results, together with several changes in the types of technology requested, indicate that the introduction of a fee for all TSP's would probably decrease the proportion of Mode 2 and 3 applications (i.e., the technology transfer activity). This, in turn, would decrease both the benefit-to-cost ratio and the tax revenues from corporate benefits. The expected benefits, in the aggregate, are probably not a good indicator of each requester's willingness to pay because he/she is very uncertain concerning their individual benefits. The process for purchasing government publications, rather than the price charged, appears to have a significant effect on TSP transactions and this effect may also occur if a charge were introduced for Tech Briefs.

TABLE IV-1. FEDERAL TAXES FROM NET BENEFITS FOR MANUFACTURING CORPORATIONS*
(in thousands of dollars)

	Mode 2 Cases	Mode 3 Cases	Taxable Benefits	Tax Rate**	Federal Taxes
(Net Benefit per Case)	($4.9-5.0)	($22.6-31.1)			
Benefit Type:					
Mfg. Cost Saving	4,652	363	$31,000-34,500	15-25%	$4,650-8,650
Mfg. Profit Increase	0	362	8,200-11,250	45%	$3,700-5,050
Non-Mfg.	3,323	0	—	—	—
Totals	$7,975	$725	$39,200-45,750		$8,350-13,700
				NASA Cost:	$6,364

*Current value of tax revenues based on discounted net benefits
**Estimated from 1974 Corporation Income Tax Returns, Internal Revenue Service Publication 159 (1-77). For the SIC groups which have a significant representation in the Data Bank, the tax rate is 46 ± 1 percent of net income subject to normal tax and 20 ± 5 percent of operating cost savings. The latter rate is due to the coefficient for C/I in the equation T/I = .159 R/I - .193 C/I where: T = normal taxes paid; I = net income subject to normal tax; R = total receipts; and C = cost of sales and operations. The correlation coefficient for R/I and C/I is .995.

Recommendations

Three different types of recommendations can be made based on the statistical analyses in this study. They relate to improvements in the Tech Brief Program, other applications of the same methodology, and further development of a statistical model for how economic benefits are obtained from technology.

Program improvements. This study provides a baseline that should be updated annually to evaluate program changes in the previous year, and to provide a feedback loop which is critical to the improvement process. In 1977, for example, the effect of introducing the new journal format, NASA Tech Briefs, in 1976 should be analyzed by the same method to compare the increased costs with net benefits for the new format. A Program Advisory Committee, mainly composed of experienced TSP requesters, could also provide valuable information and insights from the user's point of view.

Opportunities for decreasing program costs are readily identified in the study results. Figure IV-1 shows the distribution of TSP's according to request frequency. If those TSP's which receive fewer than five requests could be predicted with some degree of reliability during the screening process, their production costs could be avoided with little change in benefits. TSP's with few requests generally have a low probability of increasing the expected net benefit per TSP request. Other transfer mechanisms could be specified for the technology in these TSP's. Cross tabulations of interview sample data for application modes and technology variables (e.g., subject area and field center) indicate the feasibility of developing a technology classification scheme that correlates with application modes. Such a classification might be used in the screening process to reduce the number of TSP's with few requests.

Several opportunities for increasing the proportion of requesters in Modes 2 and 3 can also be identified. One such opportunity is indicated by the fact that relatively few TSP requests are coming from small and medium size manufacturing firms (see Figure A-7). These firms constitute a large majority of the total manufacturing firms. An analysis of the Data Bank could be used to identify the combinations of technology, application and industrial variables most often associated with Mode 2 and 3 benefits. This information could then be used in designing a market package to promote wide use of selected TSP's by small firms, for example. The economic effect of this effort could be measured and, if necessary, used to redesign the marketing approach. The advantages offered by this approach are: low additional cost; substantial increase in potential user population; and expected benefits per user of approximately the same magnitudes as found in the current data for Modes 2 and 3.

Another opportunity is based in part on the Comparative Channels Study, reported in the 1975 TRIS Annual Report, which investigated the additional transfer activity for a TSP that was reproduced and distributed by a professional society. A systematic approach may be possible for identifying TSP's which might be republished by professional societies and distributed to a new (and more specifically relevant) audience. The potential effect on net benefit is similar to the previous opportunity.

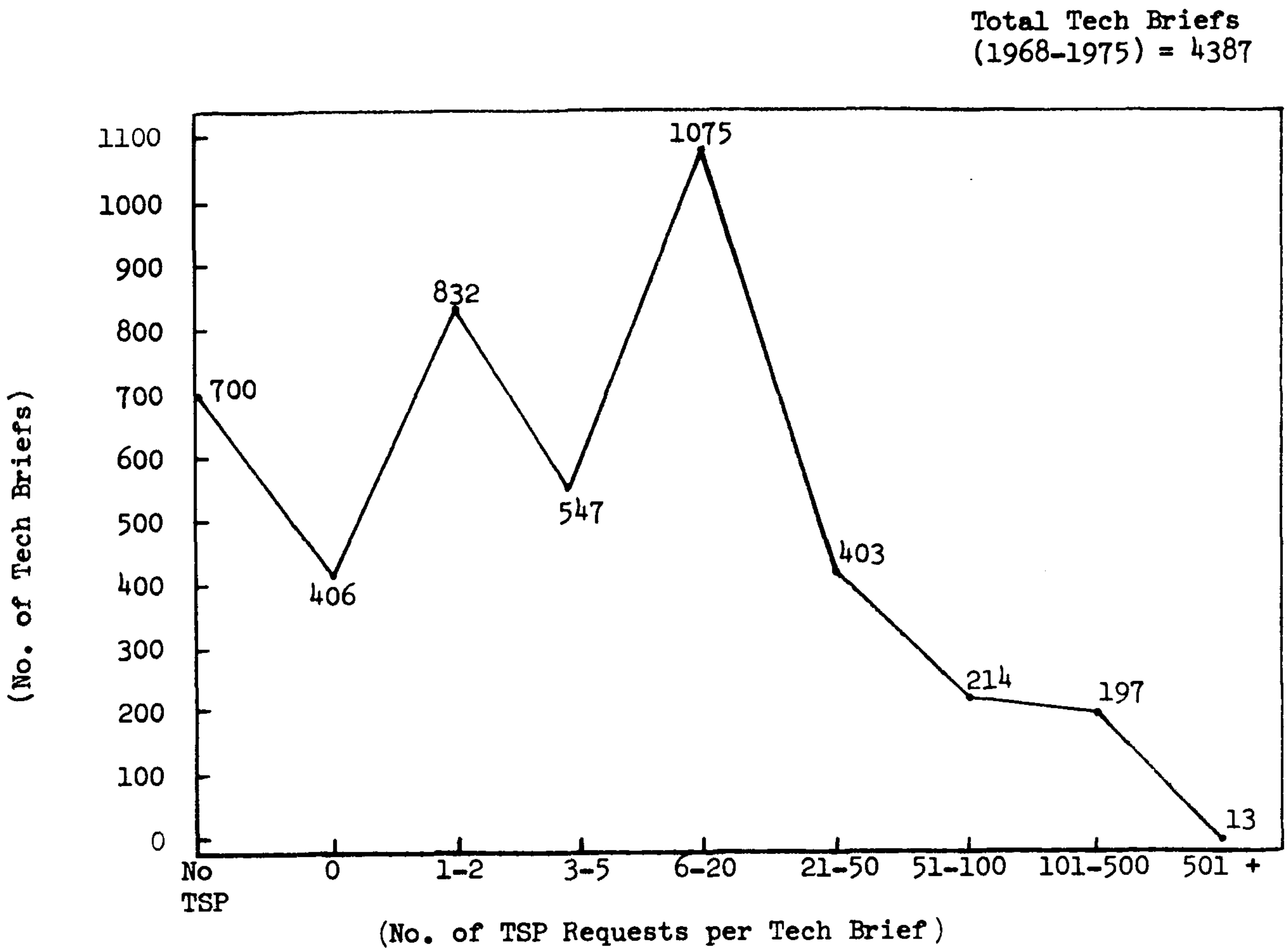


Figure IV-1. Distribution of All Tech Briefs for 1968-1975 by TSP Request Frequency.

<u>Other CBE applications</u>. This statistical methodology for cost benefit evaluation was designed to have general applicability, with the availability of program data being a primary consideration with regard to other applications. The estimated data availability for all TUO Program elements is outlined in Table IV-2. A large number of TSP requests (over 250,000) from SBA Publications and TU Compilations will be added to the TRIS Data Bank in 1977. These requests should be sampled and analyzed to determine the expected net benefit value per TSP request through these mechanisms.

TABLE IV-2. DATA AVAILABILITY FOR TUO PROGRAMS

	Users	Uses	Benefits
IAC'S	2	1-2	1-2
COSMIC	2	1-2	1-2
AT, AE Projects	2	2	1-2
Publications: Tech Briefs	3	3	2-3
TU Compilations	3	1	1
Special Publications	1	1	1
TU Conferences	2	1	1
Field Center TU Officers	1-2	1	1

1. Very little data
2. Data exist but are not ready for analysis
3. Data exist and are ready for analysis

The study methodology appears to be applicable, with minor outside assistance, by the current staff at COSMIC and several Industrial Application Centers. If this effort was implemented, it should soon be possible to characterize the expected net benefits and the types of technology best suited for each transfer mechanism. A unit of analysis--comparable to a TSP transaction for the TUO Publications Program--would have to be defined for each mechanism in order to apply the methodology. The resulting common quantitative base would facilitate the selection of transfer strategies that coordinate the best features of each mechanism and support the TU Program objective of "widest possible dissemination and utilization."

In addition to the formal transfer programs operated by NASA, there are seven other transfer modes (see Table I-3). It should be possible to define a unit of analysis for each mode and design a sampling procedure so that data could be collected and analyzed by the same methodology. Thus, it is theoretically possible to measure the net benefits expected for any unit of technology flow from the Agency. This result, together with an estimate of the number of units, would provide an estimate of net benefits for a transfer mode. The cost of obtaining this estimate, however, might vary substantially for the different transfer modes, and may indeed be prohibitive in some areas.

Statistical model. The statistical results of this study appear to provide the basis for a model of how economic benefits are achieved from technical information generated by federally funded R&D. The economic increments are modest but the aggregate effect appears to be a very good investment. This effect can probably be improved through a statistical model. Some of the opportunities outlined above (e.g., a technology classification method related to expected benefits) would contribute to the development of such a model. A systematic program of random sampling and analysis is recommended to develop several key factors which are indicated by the following hypotheses:

- Mode 1 may be better represented by two exponential distributions which characterize unmanaged information acquisition processes, whereas a normal distribution may characterize this process when the risk (i.e., uncertainty) is managed.

- Modes 2 and 3 are represented by lognormal distributions which are probably due to the multiplication of production factors; only one factor is affected when the application is not institutionalized (i.e., it affects only one individual's time) and the submode distribution for such applications is normal.

- The rate of declining technological utility is mainly determined by the rate of technological change in sectors related to the application for institutionalized Mode 2 and 3 cases, but for individual Mode 2 cases the rate of technical personnel turnover is more appropriate.

- The time evolution from a TSP request to the final application is a stochastic process that depends primarily on the technology, and organizational variables such as the Standard Industrial Classification group; net benefits appear to be predictable with a reasonable reliability from these variables.

Summary

The study methodology and data revealed a surprising regularity that suggests an underlying rational process, in the aggregate, for the acquistion, application and benefits of new technology. This process and its economic results are apparently amenable to sampling and measurement at the micro level of economic growth. The present capability to do so, as indicated in the study results, appears to be sufficient for significant practical applications in TUO Programs. Further development of this capability offers even greater potential for programmatic applications.

APPENDIX A. TECHNICAL SUPPORT PACKAGE REQUEST DATA

A primary continuing task for the TRIS Project is the maintenance of a three-phase Data Bank to monitor and evaluate NASA's Tech Brief Program (see Figure II-2 in Section II). About 120,000 TSP requests, generated directly or indirectly by Tech Briefs, have been entered since 1968. These data represent only a portion of the total TSP requests generated by the Agency's TUO Publications Program. The four subsections in this Appendix provide aggregate data for the total requests and each phase of the Data Bank.

Total Requests

After new technology has been reported, it is screened and evaluated by TUO to identify those innovations which appear to have utility for other applications (see Figure I-1 in Section I). Documentation for these innovations becomes the technology resource that is announced through brief descriptions prepared by TUO and others, particularly the Small Business Administration and trade journals. Figure A-1 shows the annual TSP requests due to three announcement mechanisms: Tech Briefs; Technology Utilization (TU) Compilations; and SBA publications. The Compilations and SBA publications have generated approximately 250,000 TSP requests which are not currently in the Data Bank. Statistical sampling in 1974 indicated that the applications and benefits for these TSP requests are generally similar to Tech Brief-initiated requests (Staskin, et al., 1974).

The annual Tech Brief production and size of the Tech Brief mailing list are shown in Figures A-2 and 3. Two significant groups of technology recipients through this announcement mechanism are not represented in the Data Bank: (1) those who request TSP's from the National Technical Information Service (NTIS) or NASA's Computer Software Management Information Center (COSMIC) and (2) all recipients of Tech Briefs which completely describe an innovation and no TSP is required. Between 7 and 15 percent of all Tech Brief-initiated TSP requests are handled by NTIS or COSMIC; data for these transactions are not forwarded to TRIS for inclusion in the Data Bank. Approximately 17 percent of the Tech Briefs do not have TSP's and the mailing list has never been sampled to estimate the probable benefits due to these one-way transactions.

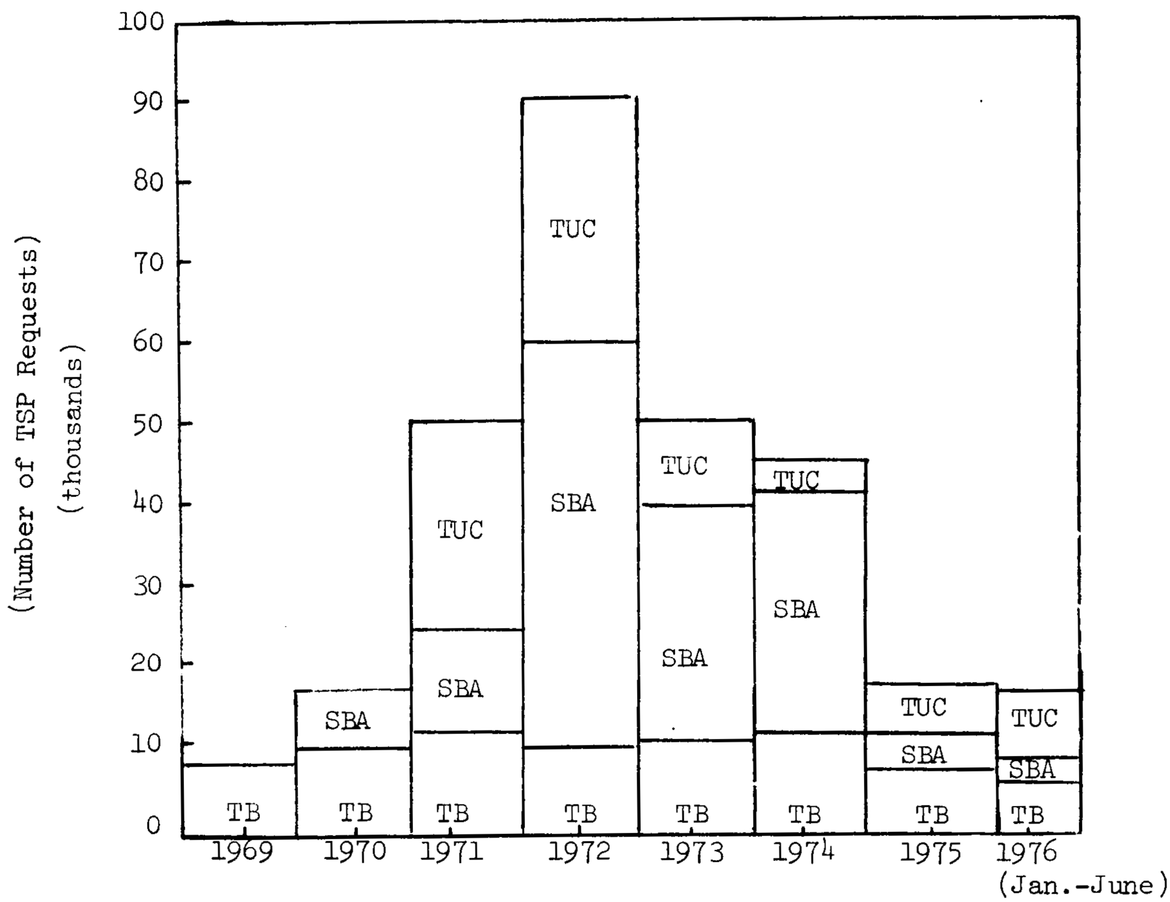


Figure A-1. Annual Number of TSP Requests by Mechanism: Tech Briefs, SBA Publications and TU Complications.

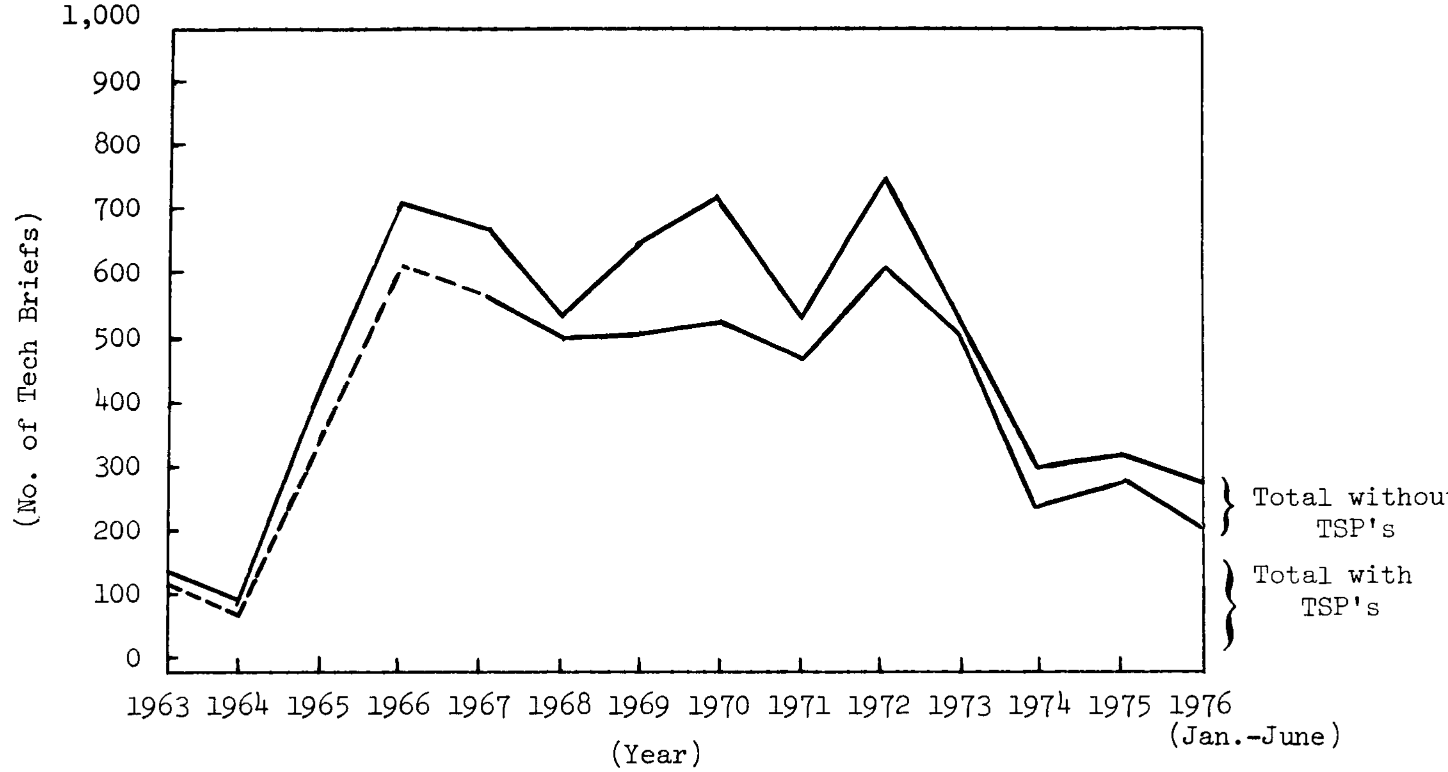


Figure A-2. Tech Brief Production by Year.

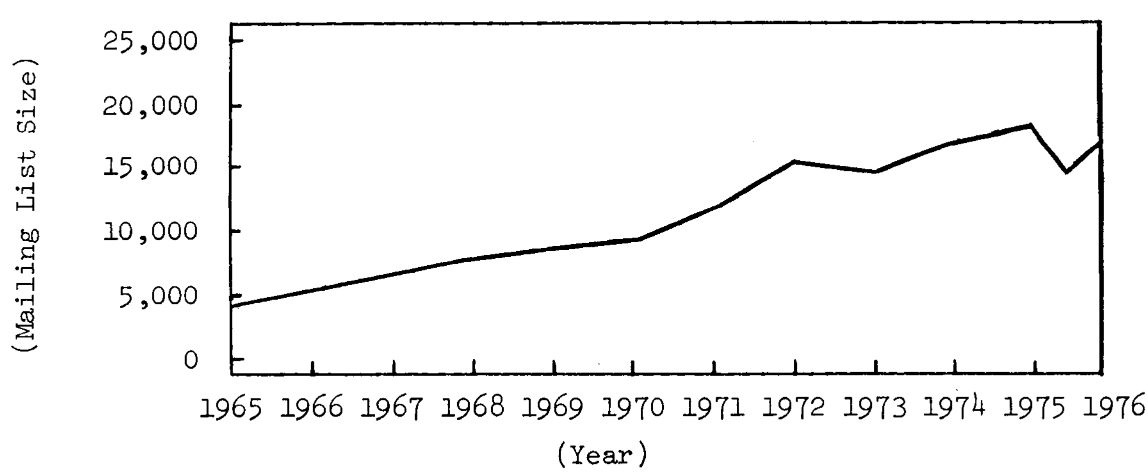


Figure A-3. TSP Mailing List by Year.

Note: Tech Brief mailing list was culled in mid-1975.

Phase I Data Bank

All TSP request data received by TRIS are coded and entered on standard computer tapes. In addition to assigning a unique case number for each TSP transaction, the following data are coded:

- Technology variables (TSP reference number, technical subject area and NASA Field Center source);
- Requester variables (organization name, size, location, and two-digit Standard Industrial Classification Code); and
- Time variables (date of request, Data Bank entry, and six-month questionnaire follow-up).

Figure A-4 shows the number of TSP requests entered for each year since 1968. Figure A-5 shows the annual percentages of Tech Briefs for different TSP request frequencies and Table A-1 lists the 50 most frequently requested TSP's. Figures A-6 and 7 show the distribution of Phase I requests by the TSP technical subject area and by the location, SIC code and size of the requesting organization.

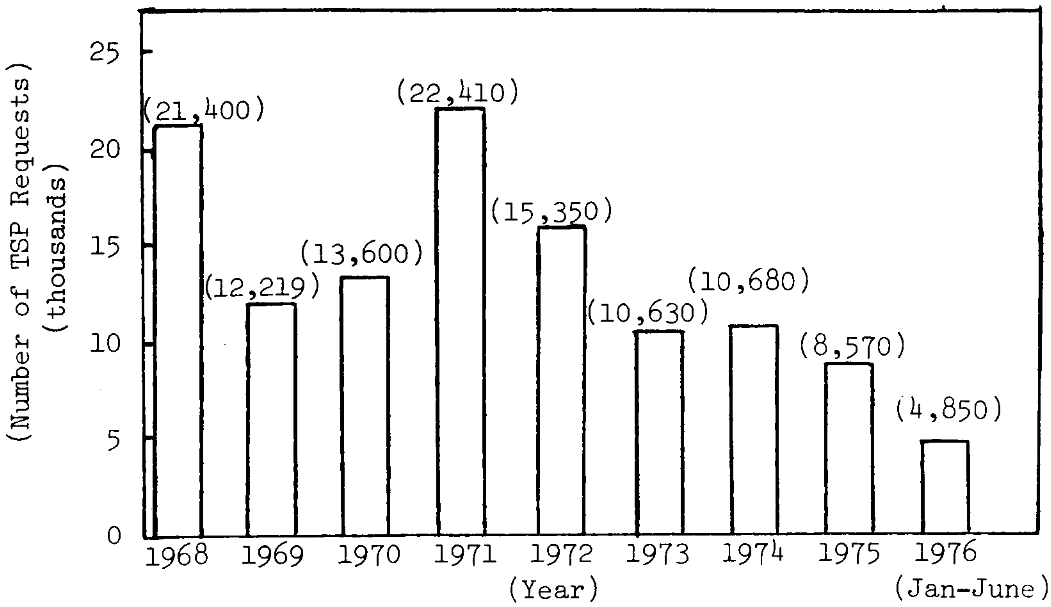


Figure A-4. Number of TSP Requests Entered by Year.

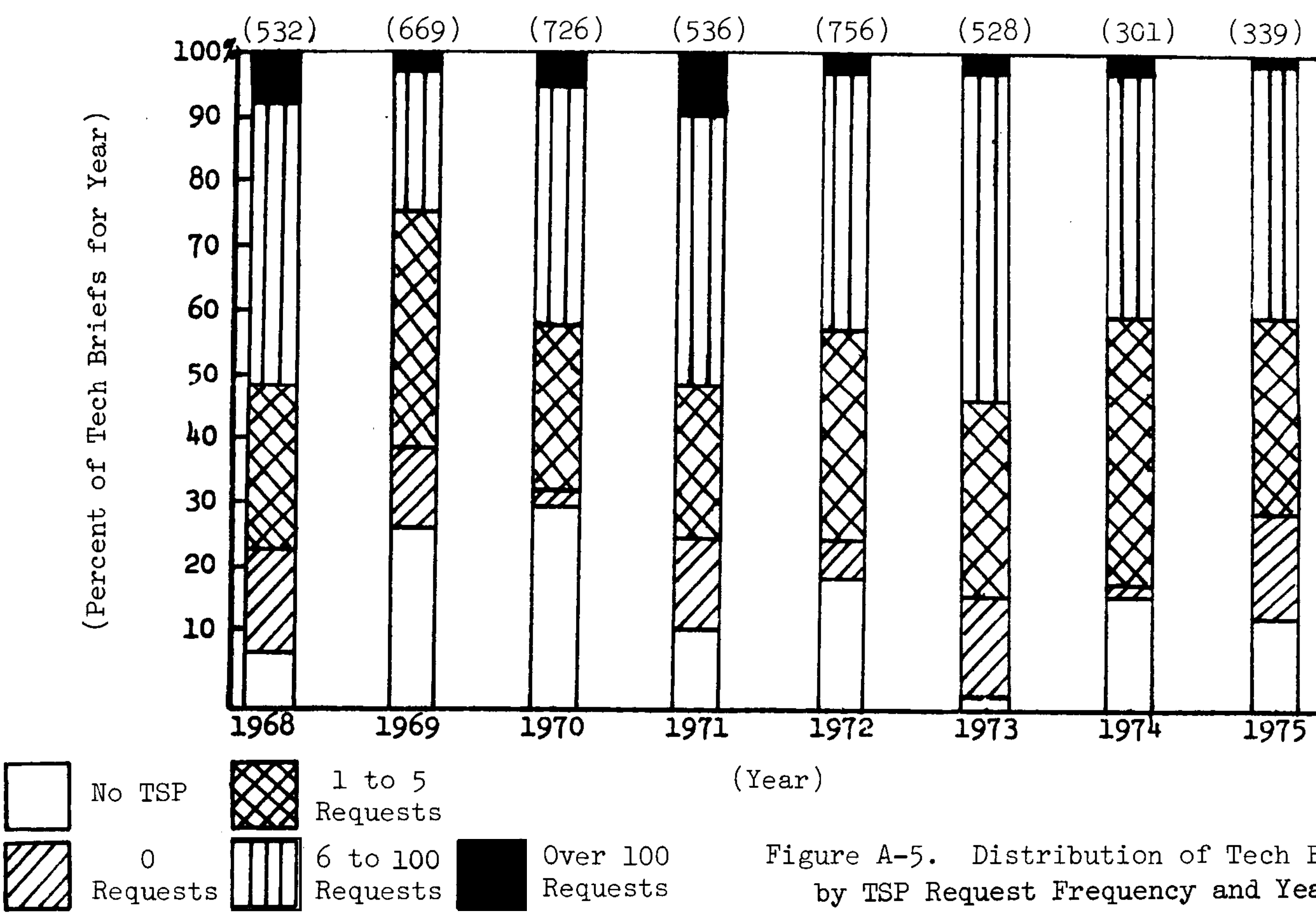


Figure A-5. Distribution of Tech Briefs by TSP Request Frequency and Year.

TABLE A-1. FIFTY MOST REQUESTED TECHNICAL SUPPORT PACKAGES

TECH BRIEF NO.	TITLE AND FIELD CENTER	NO. OF REQUESTS
73-10156	A Practical Solar Energy Heating and Cooling System (MSFC)	2350
67-10200	Workmanship Standards for Fusion Welding (SNPO)	1614
70-10520	Nondestructive Spot Tests Allow Rapid Identification of Metals (LARC)	1342
75-10189	Comparative Performances of 23 Types of Flat Plate Solar Energy Collectors (LERC)	1316
68-10392	Contamination Control Handbook (MSFC)	1164
68-10069	Principles of Optical-Data Processing Techniques (GSFC)	1009
69-10705	Handbook Explaining the Fundamentals of Nuclear and Atomic Physics (SNPO)	947
73-10322	Characteristics of Fortran (LARC)	887
67-10197	New Class of Thermosetting Plastics has Improved Strength and Chemical Stability (LARC)	859
73-10062	Lubrication Handbook (MSFC)	775
73-10373	Materials Data Handbooks on Aluminum Alloys (MSFC)	726
67-10440	Fluid Properties Handbook (MSFC)	606
73-10448	Motivation Techniques for Supervision (JSC)	600
72-10456	Radiation Induced Nickel Deposits (LERC)	559
70-10715	Strain Gage Installation Manual (MSFC)	525
72-10114	High Speed, Self-Acting, Face-Control Shaft Seal Has Low Leakage and Very Low Wear (LERC)	512
68-10017	Regulated DC-to-DC Converter Features Low Power Drain (GSFC)	496
71-10149	Inexpensive Anti-Fog Coating for Windows (JSC)	469
70-10255	Biological Handbook for Engineers (MSFC)	457
65-10156	Inorganic Paint is Durable, Fireproof, Easy to Apply (GSFC)	440
72-10494	A System for Early Warning of Bearing Failure (MSFC)	425
69-10725	Pocket-Sized Tone-Modulated FM Transmitter (NPO)	401
73-10397	Materials Data Handbooks on Stainless Steel (MSFC)	388
68-10073	New Microelectronic Power Amplifier (LERC)	385
68-10224	Semiconductor AC Static Power Switch (MSFC)	384
70-10543	Easy Manual Operation of Overhead Garage Doors: A Concept (KSC)	365
73-10527	Selective Coating for Collecting Solar Energy on Aluminum (MSFC)	356
67-10568	Graphic Visualization of Program Performance Aids Management Review (NPO)	354
68-10397	Charts Designate Probable Future Oceanographic Research Fields (MSFC)	353
68-10391	Training Manuals for Nondestructive Testing Using Magnetic Particles (MSFC)	349
74-10280	Reliability Data for Electronic and Electromechanical Components: A Report (NPO)	335
74-10249	Liquid-Cooled Liner for Helmets (ARC)	333
67-10348	Computerized Parts List System Coordinates Engineering Releases, Parts Control and Manufacturing Planning (SNPO)	331
64-10171	Subminiature Biotelemetry Unit Permits Remote Physiological Investigations (ARC)	318
66-10057	Miniature Bioelectronic Device Accurately Measures and Telemeters Temperature (ARC)	308
70-10483	A Conceptual Current Surge Protector for Incandescent Lamps (MSFC)	299
67-10005	Digital Computer Processing of X-Ray Photos (JPL)	295
73-10396	Materials Data Handbook on Inconel Alloy 718 (MSFC)	289
68-10095	Cobalt Tungsten, Ferromagnetic High Temperature Alloy (NPO)	288
71-10194	Predicting Service Life Margins (MSFC)	287
70-10638	Intruder Detection System (ARC)	280
71-10198	Improved Fire Resistant Coatings (ARC)	276
68-10385	Electromotive Series Established for Metals Used in Aerospace Technology (MSFC)	272
68-10358	Fire Retardant Foams Developed to Suppress Fuel Fires (LERC)	270
67-10510	Probabilistic Approach to Long Range Planning of Manpower (JSC)	269
71-10256	Plating by Glass-Bead Peening (GSFC)	264
74-10016	Plasma Sprayed Metal-Glass Fluoride Coatings for Lubrication to 117° K (1650° F) (LERC)	263
70-10511	Metal Detector System (ARC)	259
67-10340	High-Strength Tungsten Alloy with Improved Ductility (LERC)	259
	TOTAL	26,908

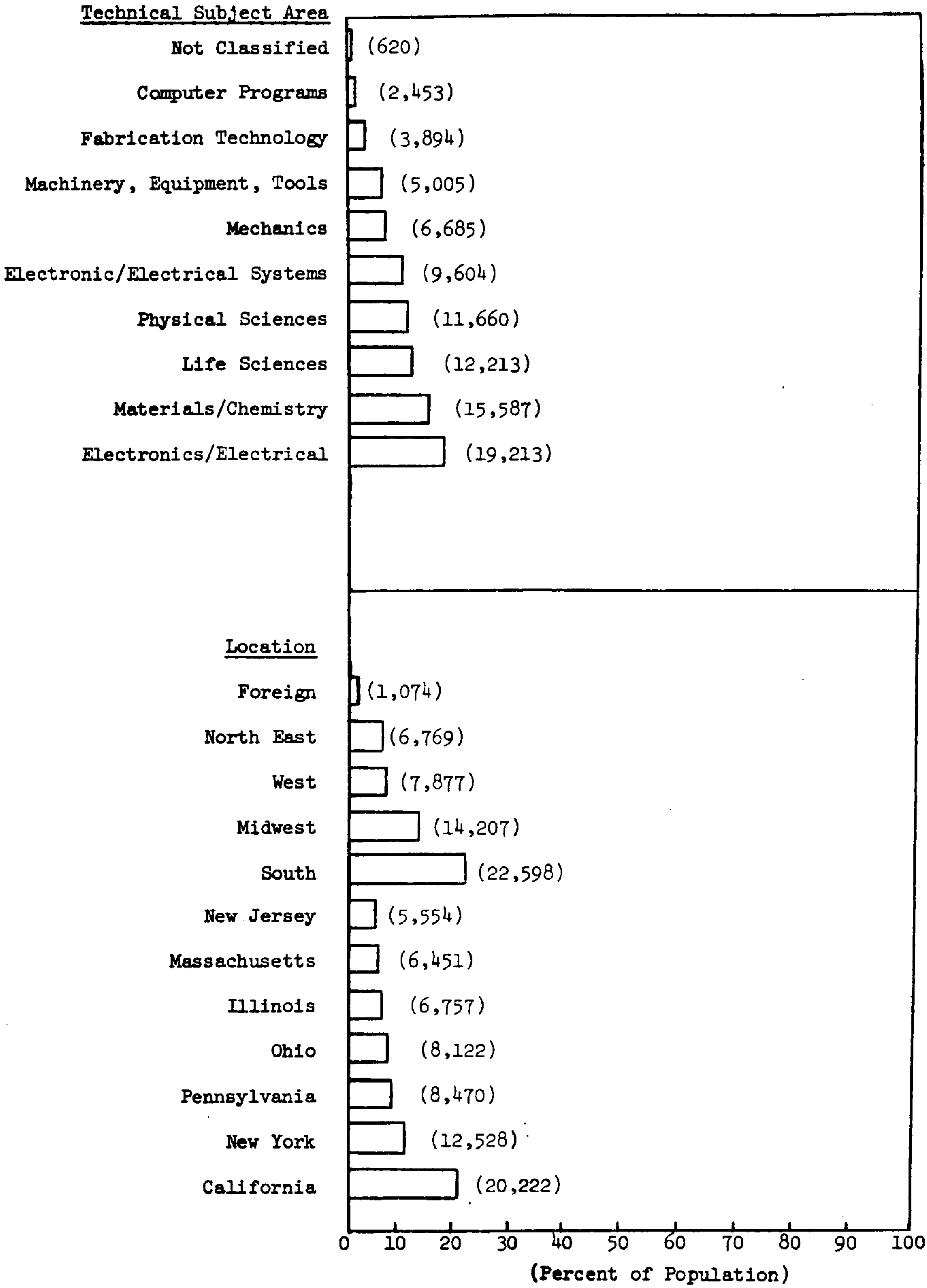


Figure A-6. Phase I Data Bank Distribution by Technical Subject Area and Location of Requester Observations.

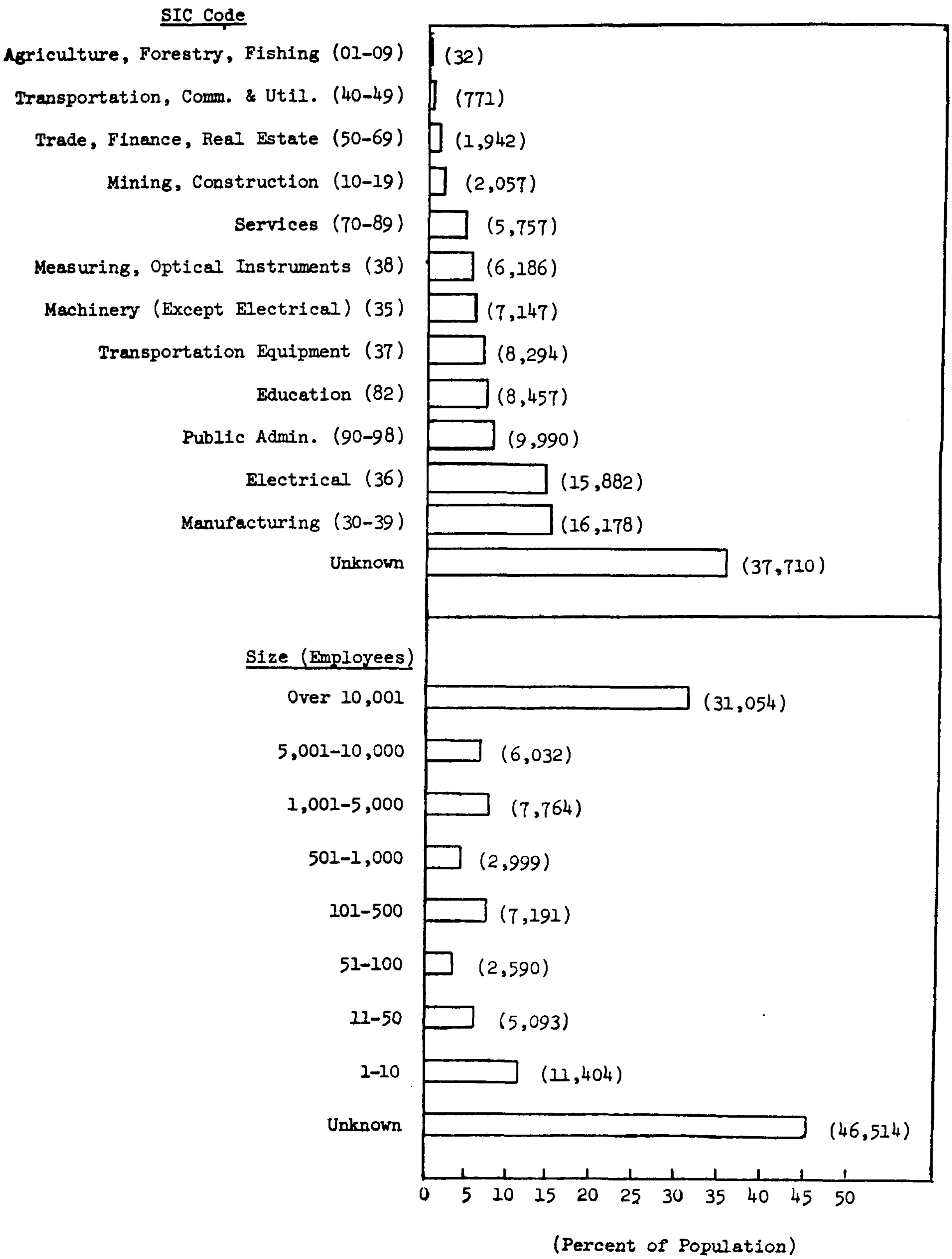


Figure A-7. Phase I Data Bank Distribution by SIC Code and Size of Requesting Observations.

Phase II Data Bank

The Phase II Data Bank contains the responses from a mail questionnaire survey sent to a 40 percent random sample of the Phase I TSP requests. The TSP questionnaires are routinely mailed six months after the request date (see Appendix C for questionnaire samples). The response rate is approximately 60 percent, so Phase II contains questionnaire data for about 24 percent of the Phase I requests. While these data are not routinely coded for computer analysis, random samples of returned questionnaires have been coded and analyzed. Data from the random sample (n = 680) for the current study are presented in this subsection.

Questionnaire data include transfer variables such as requester job function, type of organization, source of TSP awareness, type of objective for the TSP application, progress (after six months) of the transfer activity through four stages from initial awareness to routine use, level of interest in and importance of the TSP, and the amount and type of benefits. A factor analysis was conducted for the questionnaire sample used in this study and most of the variance in benefit responses was due to four variables: level of importance; level of interest; progress through transfer stages; and type of objective (e.g., improved process or new product). Figures A-8 and 9 show the distributions for these four variables, together with source of awareness and primary use of the TSP. Note that less than half of the TSP requests were generated directly by Tech Briefs and the remainder were generated by a variety of redistribution mechanisms for the Tech Briefs. This indicates that an important function is performed by redistributors on the Tech Brief mailing list.

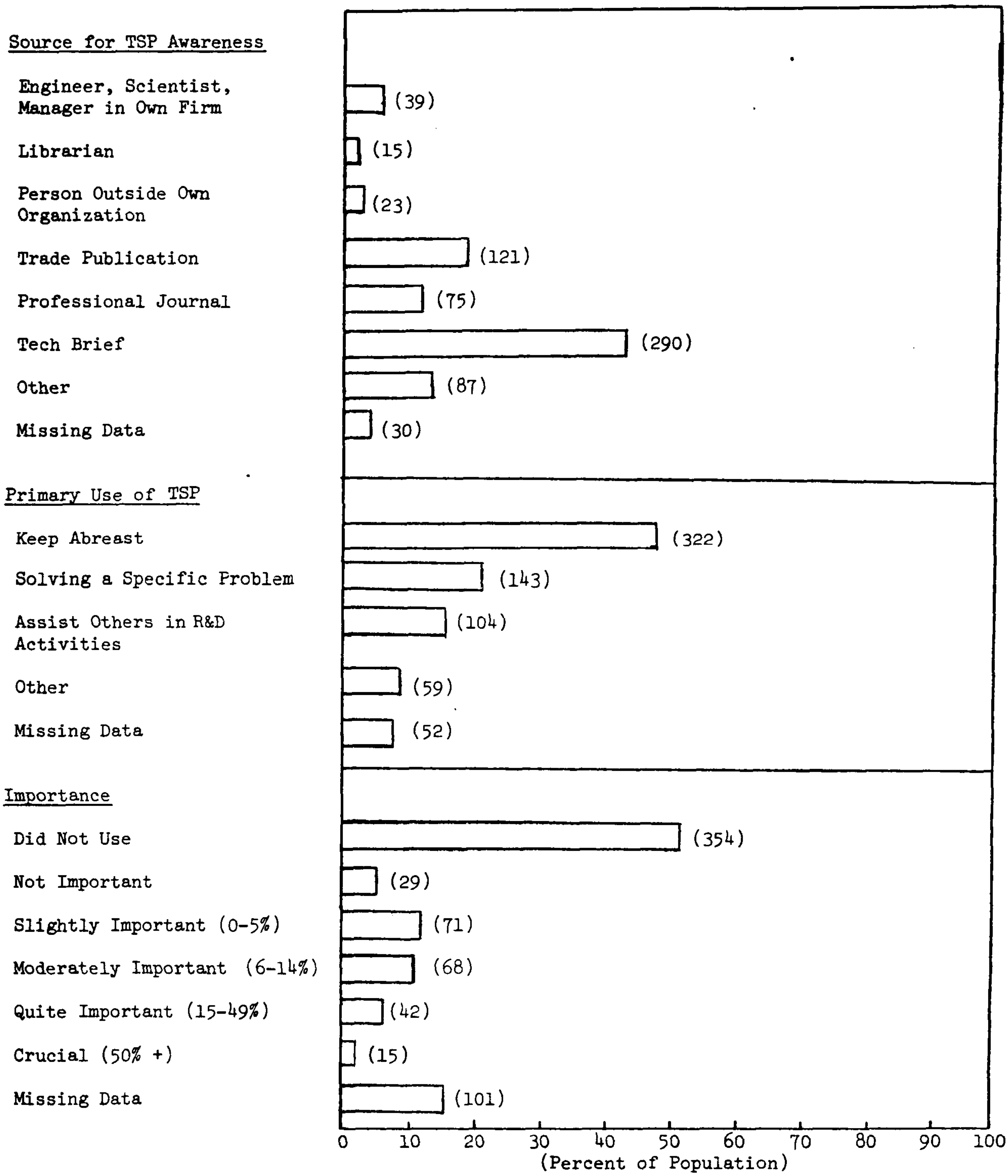


Figure A-8. Phase II Data from Random Sample of 680 Questionnaires in Survey.

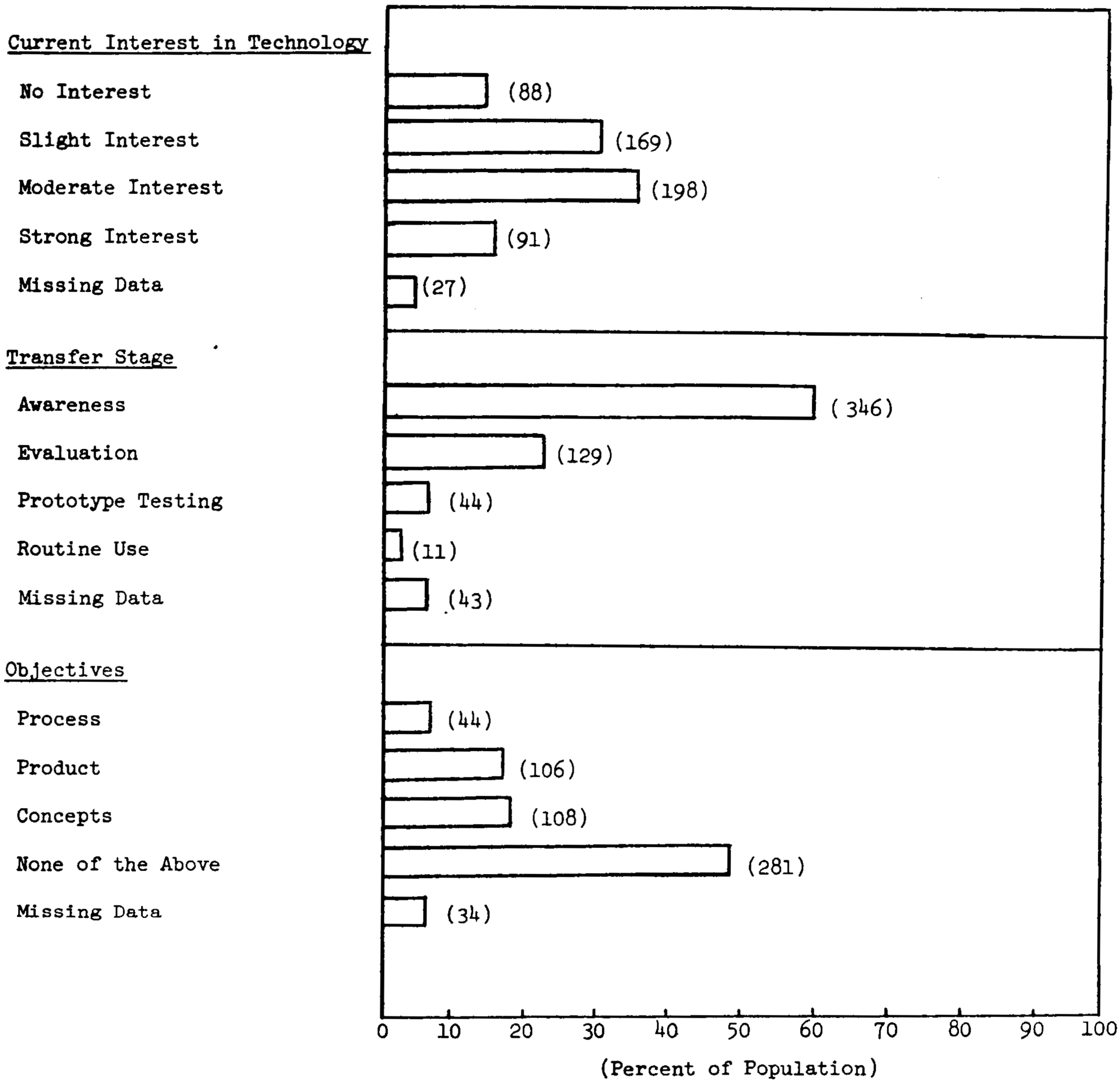


Figure A-9. Phase II Data from Random Sample of 573 Questionnaires in Survey.*

*107 older questionnaires were excluded since these questions did not appear on them.

Phase III Data Bank

The Phase III Data Bank contains written documentation for about 1,400 individual transfer cases involving NASA technology. This phase is stored in an automated microfilm system for access by combinations of 11 transfer variables such as application/technical subject area (400 areas and subareas), type of application, benefits and transfer mechanism. The TSP-related cases in Phase III are not a random sample of TSP requests. They were selected for interviews based on questionnaire responses, as well as data requirements for transfer research on specific technologies (e.g., contamination control) or applications (e.g., pollution monitoring or electric power industry). Data from these cases provide a reasonable qualitative characterization of TSP applications and benefits, but they cannot be used for quantitative estimates such as the proportion of TSP requests that fit a given characteristic pattern.

Interviews have also been conducted to analyze transfer activity for seven non-TUO transfer modes (see Table I-3 in Section I). About 35 percent of the Phase III cases do not involve the formal TUO Programs. Figure A-10 shows the distribution of Phase III according to transfer mechanism, including multiples when more than one mechanism was involved. Figure A-11 shows the Phase III distributions for transfer stage, application type and benefits. In each case, only data from the most recent interview are used.

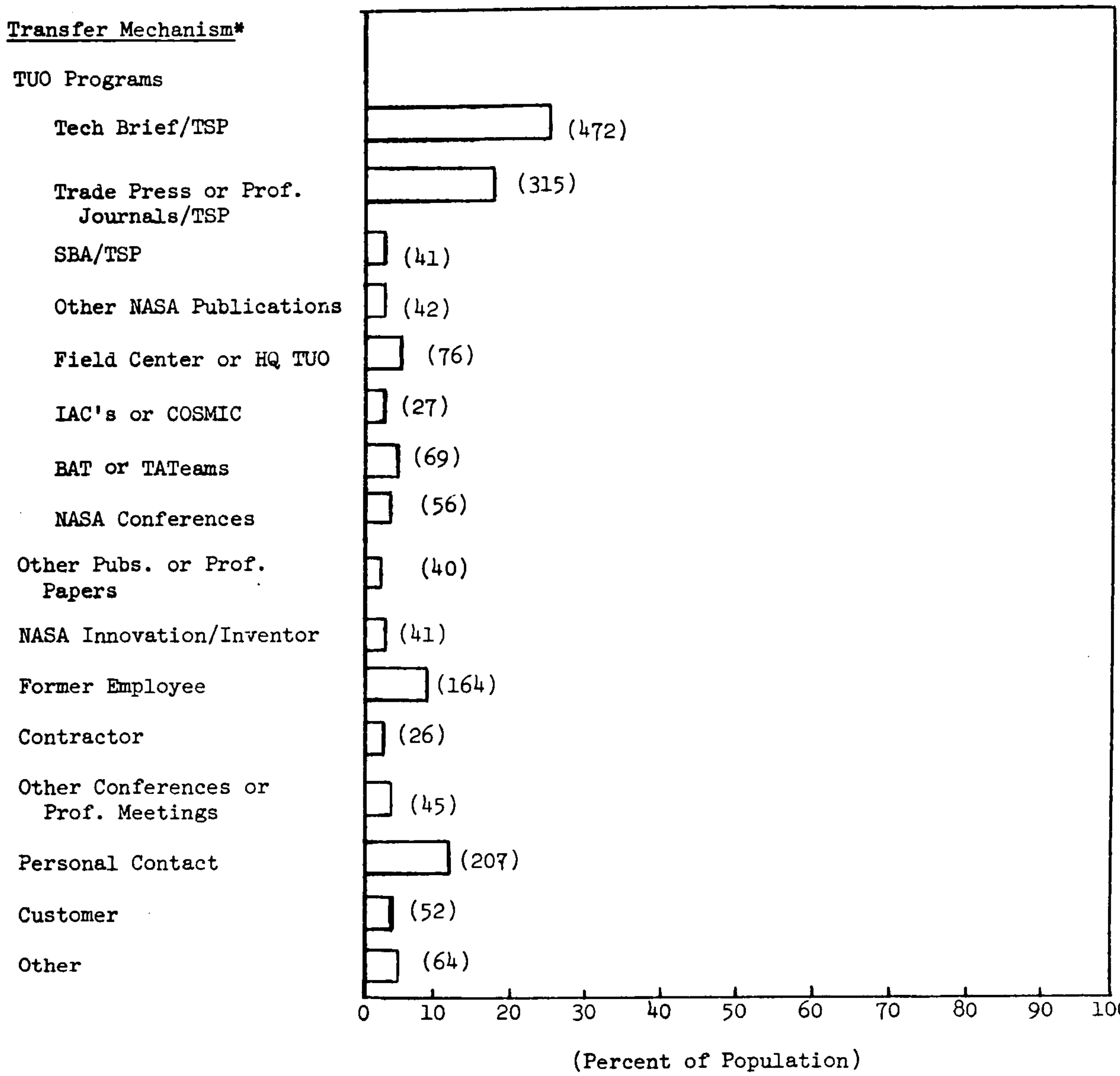


Figure A-10. Phase III Data Bank Distribution by Transfer Mechanism.

*Combinations are counted as multiple entries in the figure.

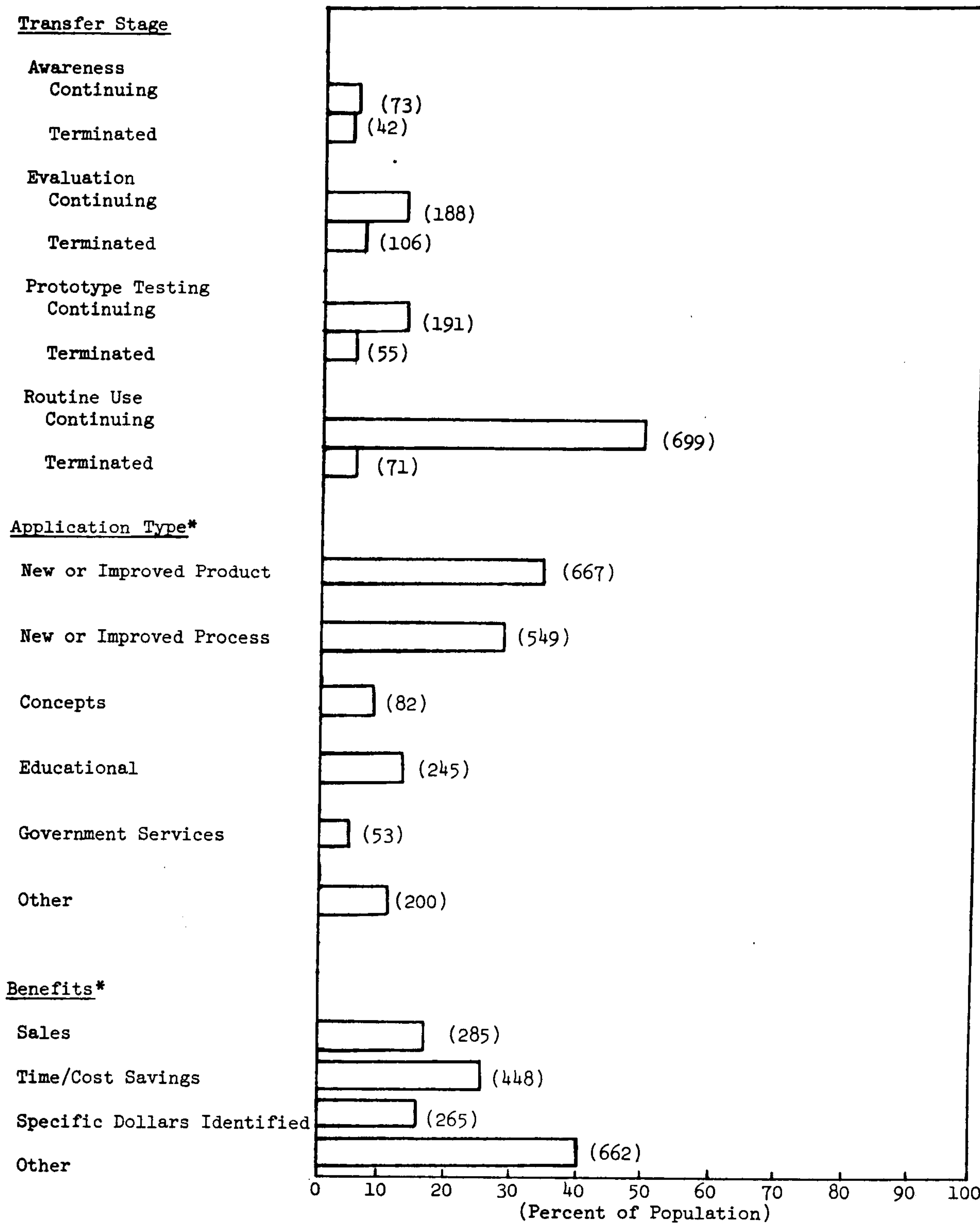


Figure A-11. Phase III Data Bank Distribution by Transfer Stage, Application Type and Benefits.

*Combinations are counted as multiple entries in the figure.

APPENDIX B. STUDY METHODOLOGY AND DATA

The study methodology was presented in Section II. This appendix provides further details for three aspects of the methodology: net benefit discounting method; distributions for sample cells; and distribution tests for net benefits in the application modes.

Discounted Cash Flow

The discount rate is generally the critical issue for determining the present value of net benefit streams. The typical application for discounted cash flow (DCF) in cost benefit analyses (CBA) is to compare alternative plans with regard to their implementation costs and anticipated future benefits. It is important in such comparison to adjust for the difference (in present value) between a $1,000 benefit next year and the same magnitude of benefit two years from now (Mishan, 1975). By applying DCF, the evaluator is adjusting for this difference by calculating how much money the beneficiary would have to avoid spending this year and save at some interest rate in order to have $1,000 next year or two years from now. At a 5 percent interest rate, this would be $952 for next year's $1,000 and $907 for two years from now. These amounts are the present values for $1,000 benefits at the two different times using a 5 percent discount rate.

There is, however, an issue in cost benefit evaluation (CBE) which is more fundamental than the discount rate. In this type of evaluation, the benefits under consideration include both past and future values. The issue is whether to treat actual benefits in the past as if they were dollars saved at some interest rate <u>or</u> to treat them as singular beneficial events in the past, since benefits from the decision to reinvest the savings may not be attributable to the decision to use the TSP which generated the savings. The issue is illustrated by the following example. Suppose a TSP requester receives a one-time cost savings benefit (net) of $1,000 in 1971 (assume the amount is given in 1976 dollars, rather than 1971 dollars). For the purpose of evaluating the program that provided that benefit, should it be counted as a $1,000 or a $1,276 ($1,000 saved for five years at 5 percent interest) benefit in 1976?

One might argue by symmetry that if an expected $1,000 benefit for 1977 is counted as $952 in 1976, then an actual $1,000 benefit for 1971 should be counted as $1,276 in 1976. While this approach turns out to be correct, the reason used to justify it is insufficient. A very good reason is the following fundamental criteria for analytic methods in program evaluation--analytic methods should provide a program evaluation result that does not depend on when the evaluation is performed (Bortz, 1977). In particular, three evaluations of program activity for the time period 1971 to mid-1976, for example, should produce the same benefit-to-cost ratio even if one evaluation is done in 1965 (assuming a perfect CBA evaluation), one is done in 1976, and one is done in 1990 (assuming the recipients have perfect memories). Any variation in the actual results should depend only on the reliability of data, not on the data analysis methods.

The appropriate DCF method was derived by using the stated criteria and selecting a discount rate for this study. The derivation was based on considering each year of Tech Brief Program operations separately and then combining these results in a weighted average for the 5 1/2-year period. Assume that TUO would have decided in each year whether or not to continue the Program, and the decision would have been based on standard economic analyses used in business planning. In 1972, for example, TUO would consider the benefit-to-cost ratio for Program costs that year, together with the benefits for 1972 and anticipated for subsequent years due to 1972 program operations. The anticipated future benefits would be discounted to their 1972 value at some interest rate (r).

The mathematical derivation is based on the following notation:

D_i = NASA's cost for program operations in the i^{th} year ($i = 1971, \ldots, 1976$).

C_{ij} = Total cost in the j^{th} year due to all TSP requests in the i^{th} year (for these data $C_{ij} = 0$ when $i \neq j$); ($j = 1971, \ldots, 1976, \ldots, n$).

B_{ij} = Total gross benefits in the j^{th} year attributed to all TSP requests in the i^{th} year (Note that B_{ij} = 0 when $j<i$); ($j = 1971, \ldots, 1976, \ldots, n$).

The benefit-to-cost ratio for the i^{th} year operations only is:

$$R_i = \frac{\sum_{j=1971}^{n} (B_{ij} - C_{ij})\ (1 + r)^{i-j}}{D_i}$$

In order to evaluate the Program performance over a time period (1971-1976), these annual ratios must be averaged. There are two reasonable ways to formulate a weighted average of the annual ratio: (a) weighted by the annual Program costs D_i and (b) weighted by the annual Program costs discounted to their 1976 value (or whatever year the evaluation is performed) which is $D_i\ (1 + s)^{1976-i}$. The second method gives more weight to earlier Program costs than to more recent costs. The first method yields:

$$R_a\ (1971\text{-}1976) = \frac{\sum_{i=1971}^{1976} R_i D_i}{\sum_{i=1971}^{1976} D_i}.$$

$$= \frac{\sum_{i=1971}^{1976} \sum_{j=1971}^{n} (B_{ij} - C_{ij})\ (1 + r)^{i-j}}{\sum_{i=1971}^{1976} D_i}$$

The second method yields:

$$R_b(1971\text{-}1976) = \frac{\sum_{i=1971}^{1976} R_i D_i\ (1 + s)^{1976-i}}{\sum_{i=1971}^{1976} D_i\ (1 + s)^{1976-i}}$$

$$= \frac{\sum_{i=1971}^{1976} \left[\sum_{j=1971}^{n} (B_{ij} - C_{ij})\ (1 + r)^{i-j} \right] (1 + s)^{1976-i}}{\sum_{i=1971}^{1976} D_i\ (1 + s)^{1976-i}}$$

$$= \frac{\sum_{i=1971}^{1976} \sum_{j=1971}^{n} (B_{ij} - C_{ij})\ (1 + r)^{1976-j}}{\sum_{i=1971}^{1976} D_i\ (1 + r)^{1976-i}}, \text{ if } r = s$$

This means that all net benefit estimates and NASA costs could be discounted to their 1976 value and used to calculate the ratio since the result would equal R_b (1971-1976). The time independence criteria stated earlier was applied to the ratio from each weighted average. If the Tech Brief Program performance between 1971 and 1976 were evaluated in any year K, then the factor $(1 + s)^{k-i}$ would be used in the formula for R_b (1971-1976). This yields:

$$R_b(1971\text{-}1976) = \frac{\sum_{i=1971}^{1976} \sum_{j=1971}^{n} (B_{ij} - C_{ij})\ (1 + r)^{k-j}}{\sum_{i=1971}^{1976} D_i\ (1 + r)^{k-i}}, \text{ if } r = s$$

Multiplying numerator and denominator by $(1 + r)^{1976-k}$ shows that the ratio has not changed from R_b (1971-1976), above. The ratio R_a (1971-1976), on the other hand, does change if $K < 1970$ (i.e., this would be a CBA study before the fact). To see why this is so, let K = 1970. All the values would then have to be discounted to their 1970 value, so B_{ij} is replaced by $B_{ij} (1 + r)^{1970-j}$, C_{ij} is replaced by $C_{ij} (1 + r)^{1970-j}$, and D_i is replaced by $D_i (1 + s)^{1970-i}$. Assuming, as above, that the two discount rates are the same (r = s), then a program evaluation ratio would be obtained that differs from the previous ratio for R_a:

$$R_a\ (1971\text{-}1976) = \frac{\sum_{i=1971}^{1976} \sum_{j=1971}^{n} (B_{ij} - C_{ij})\ (1 + r)^{i-j + 1970-j}}{\sum_{i=1971}^{1976} D_i\ (1 + r)^{1970-i}}$$

A simple way to illustrate why the second method of weighted averages should be used in program evaluation is the following hypothetical example: Two programs each cost $1 million per year to operate and generated net benefits of $1 million per year except for one year when the net benefit was $2 million. Program A generated the $2 million in 1976 and Program B generated the $2 million in 1971. According to the usual evaluation criteria ("The earlier the benefits, the better."), Program B is better than Program A. The ratio R_b agrees with this evaluation, but the ratio R_a cannot distinguish between the two programs. Thus, for program evaluation purposes, all cost and benefit estimates should be discounted to their value in a selected year, typically the year of the evaluation.

The next question concerns what discount rate to use. The U.S. Office of Management and Budget has recommended a 10 percent rate for government costs, so s = .10. The value for r, on the other hand, should be based on private sector rates. The cost of private capital is in the range 9-15 percent and opportunity costs for the private sector are in the range 15-40 percent. The benefit and cost estimates by TSP requesters are usually cost savings under $50,000, rather than large capital investments. In this context, the selection of a 10 percent discount rate, while it may be slightly conservative, appears to be reasonable, so r = .10.

Distributions for Sample Cells

The estimate of costs and benefits given for the TSP request sample in each of the eight cells are presented in Tables B-1 through 10. These values are shown in the year of occurrence, after converting to 1976 dollars and discounting to 1976 value. The two rates for declining technological utility are indicated by B(10) and

B(4-9), and the final year of the benefit stream is marked for each rate. No respondent in the sample cited continuing costs. The typical estimate included an initial, one-time cost to study and apply the technical information, but continuing benefits were actually net benefits since costs had been subtracted already to provide an estimate of time savings (i.e., to do something in less time or to do something sooner than expected).

Table B-11 shows the cell and year distributions for application modes. It is probably too early for Mode 3 applications from requests made in 1976 but the low incidence of Mode 2 and 3 applications for 1972 requests may be due to the types of technology in TSP's for that year; very few TSP's in 1972 had more than 100 requests. On the other hand, almost 10 percent of the TSP's in 1971 had over 100 requests and the technology distributed that year appears to have generated more than the normal benefits.

TABLE B-1. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1976 Year; X BQ ______ NBQ; Sample 1 only

Mode	Case No.		1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
1	113874	B		?											?	?	?	?
		C	0												0	0		
2	115064	B	156	142	129	117	106	97	87	80	73	66	61	55	747	1,169	712	1,134
		C	35												35	35		
0	113076	B	0												0	0	0	0
		C	0												0	0		
2	113560	B				5,625									5,625	5,625	-5,475	5,475
		C	150												150	150		
0	112600	B	0												0	0	0	0
		C	0												0	0		
0	113420	B	0												0	0	0	0
		C	0												0	0		
1	113450	B	?												?	?	?	?
		C	0												0	0		
1	113124	B		?											?	?	?	?
		C	0												0	0		
2	115530	B	8,320												8,320	8,320	8,320	8,320
		C	0												0	0		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	3	3	3	0

B(10) cut off year

B(4-9) cut off year

TABLE B-2. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1976 Year; ______ BQ __X__ NBQ; Sample 1 only

Mode	Case No.		1976	1977	1978										Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
1	112181	B	120												120	120	60	60
		C	60												60	60		
1	113291	B	?												?	?	?	?
		C	300												300	300		
1	115002	B			623										623	623	560	560
		C	63												63	63		
1	115810	B			?										?	?	?	?
		C	0												0	0		
0	115334	B	0												0	0	0	0
		C	0												0	0		
2	113860	B	10,000												10,000	10,000	9,500	9,500
		C	500												500	500		
1	116344	B			?										?	?	?	?
		C	0												0	0		
1	117128	B			?										?	?	?	?
		C	0												0	0		
0	118130	B	0												0	0	0	0
		C	0												0	0		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	2	6	1	0

B(10) cut off year   B(4-9) cut off year

TABLE B-3. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1974 Year; X BQ ______ NBQ; Sample 1 only

Mode	Case No.		1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984		Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
2	97564	B	454	413	375	341	311	281	255	233	210	191			2,175	3,064	2,175	3,064
		C	0												0	0		
1	103018	B	271												271	271	271	271
		C	0												0	0		
3	96748	B	6,050	5,500	5,000	4,550	4,150	3,750	3,400	3,100	2,800	2,550	2,350		29,000	40,850	10,850	22,700
		C	18,150												18,150	18,150		
1	94252	B	0												0	0	-13	-13
		C	13												13	13		
1	101772	B	0												0	0	-1,016	-1,016
		C	1,016												1,016	1,016		
0	99454	B	0												0	0	0	0
		C	0												0	0		
1	92056	B				?									?	?	?	?
		C	0												0	0		
0	96084	B	0												0	0	0	0
		C	0												0	0		
2	97287	B	242	220	200	182	166	150	136	124					1,160	1,420	1,160	1,420
		C	0												0	0		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	2	4	2	1

B(10) cut off year   B(4-9) cut off year

TABLE B-4. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1974 Year; ______ BQ X NBQ; Sample 1 of 2

Mode	Case No.		1974	Year											Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
1	97393	B	271												271	271	257	257
		C	14												14	14		
0	96362	B	0												0	0	0	0
		C	0												0	0		
0	96774	B	0												0	0	0	0
		C	0												0	0		
0	98940	B	0												0	0	0	0
		C	0												0	0		
0	95904	B	0												0	0	0	0
		C	0												0	0		
1	103232	B	?												?	?	?	?
		C	0												0	0		
0	95847	B	0												0	0	0	0
		C	0												0	0		
1	101042	B	?												?	?	?	?
		C	0												0	0		
0	95488	B	0												0	0	0	0
		C	0												0	0		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	6	3	0	0

B(10) cut off year

B(4-9) cut off year

TABLE B-5. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1974 Year; _____ BQ X NBQ; Sample 2 of 2

Mode	Case No.		1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
0	103168	B	0												0	0	0	0
		C	0												0	0		
0	95775	B	0												0	0	0	0
		C	0												0	0		
1	101564	B	?												?	?	?	?
		C	0												0	0		
1	92017	B	0												0	0	-121	-121
		C	121												121	121		
1	98574	B	?												?	?	?	?
		C	271												271	271		
1	101296	B	?												?	?	?	?
		C	81												81	81		
2	102194	B	1,058	531											1,589	1,589	1,562	1,562
		C	27												27	27		
2	97988	B	1,355	1,232	1,120	1,019	930	840	762	694	627	571	526	470	6,496	10,146	6,496	10,146
		C	0												0	0		
1	98303	B	(7,454)*												(7,454)*	(7,454)*	678	678
		C	6,776												6,776	6,776		

* Benefits figure assigned as 110 percent of cost, reported as "benefits exceeded costs."

Mode Distribution for Cell:

Mode	0	1	2	3
No.	2	5	2	0

B(10) cut off year B(4-9) cut off year

TABLE B-6. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1972 Year; X BQ ______ NBQ; Sample 1 only

Mode	Case No.		Year 1972	1973	1974	1975	1976	1977							Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
1	72948	B						?							?	?	?	?
		C	949												949	949		
1	79927	B	(1,670)*												(1,670)*	(1,670)*	152	152
		C	1,518												1,518	1,518		
1	76522	B	292												292	292	292	292
		C	0												0	0		
0	78474	B	0												0	0	0	0
		C	0												0	0		
1	78680	B	730	665											1,395	1,395	1,395	1,395
		C	0												0	0		
2	79424	B	3,037	2,617											5,654	5,654	5,300	5,300
		C	190	164											354	354		
1	78856	B						?							?	?	?	?
		C	876												876	876		
2	79070	B	2,920	1,995	1,815										6,730	6,730	6,292	6,292
		C	438												438	438		
1	78592	B	?												?	?	?	?
		C	0												0	0		

* Benefits figure assigned as 110 percent of cost, reported as "benefits exceeded costs."

Mode Distribution for Cell:

Mode	0	1	2	3
No.	1	6	2	0

B(10) cut off year B(4-9) cut off year

TABLE B-7. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1972 Year; ______ BQ X ______ NBQ; Sample 1 only

Mode	Case No.		Year: 1972	1973											Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
0	71678	B	0												0	0	0	0
		C	0												0	0		
0	77182	B	0												0	0	0	0
		C	0												0	0		
1	77416	B	0												0	0	-53	-53
		C	53												53	53		
1	80916	B	0												0	0	-547	-547
		C	547												547	547		
1	76400	B	?												?	?	?	?
		C	0												0	0		
1	79500	B		?											?	?	?	?
		C	0												0	0		
1	73561	B	?												?	?	?	?
		C	526												526	526		
1	79790	B	1,460												1,460	1,460	1,460	1,460
		C	0												0	0		
1	70374	B	712												712	712	712	712
		C	0												0	0		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	2	7	0	0

B(10) cut off year B(4-9) cut off year

TABLE B-8. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1971 Year; X BQ ______ NBQ; Sample 1 of 2

Mode	Case No.		1971	1972	1973	1974	1975	1976	1977	1978	1979	Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
0	52024	B	0									0	0	0	0
		C	0									0	0		
0	56874	B	0									0	0	0	0
		C	0									0	0		
1	55388	B	0									0	0	-66	-66
		C	66									66	66		
1	60590	B	0									0	0	-184	-184
		C	184									184	184		
1	55972	B	0									0	0	-351	-351
		C	351									351	351		
1	57236	B	81						45			126	126	126	126
		C	0									0	0		
1	51737	B	161	146								307	307	307	307
		C	0									0	0		
2	51572	B	1,087	986								2,073	2,073	1,992	1,992
		C	81									81	81		
3	59162	B	12,075	235	430	1,952	5,251	9,548	8,736	7,968	7,200	38,227	53,395	32,592	47,760
		C	5,635									5,635	5,635		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	2	5	1	1

B(10) cut off year B(4-9) cut off year

TABLE B-9. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1971 Year; X BQ ______ NBQ; Sample 2 of 2

Mode	Case No.		1971	1972	1973	1974	1975	1976	1977						Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
1	56152	B	0												0	0	-70	-70
		C	70												70	70		
1	55972	B	0												0	0	-351	-351
		C	351												351	351		
1	54688	B	0												0	0	-443	-443
		C	443												443	443		
1	53630	B	0												0	0	-322	-322
		C	(322)*												(322)*	(322)*		
0	56874	B	0												0	0	0	0
		C	0												0	0		
1	56274	B							55						55	55	16	16
		C	39												39	39		
1	53966	B	328												328	328	328	328
		C	0												0	0		
1	52304	B	876												876	876	876	876
		C	0												0	0		
3	53909	B	27,852												27,852	27,852	27,414	27,414
		C	438												438	438		

* Cost figure assigned based on average costs in related group.

Mode Distribution for Cell:

Mode	0	1	2	3
No.	1	7	0	1

B(10) cut off year B(4-9) cut off year

TABLE B-10. 1976 Value of Interview Sample Estimates in 1976 Dollars

Cell: 1971 Year; ____ BQ x NBQ; Sample 1 only

Mode	Case No.		1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Total B(10)	Total B(4-9)	Net Benefit B(10)	Net Benefit B(4-9)
0	60235	B	0												0	0	0	0
		C	0												0	0		
0	59738	B	0												0	0	0	0
		C	0												0	0		
0	60167	B	0												0	0	0	0
		C	0												0	0		
0	59806	B	0												0	0	0	0
		C	0												0	0		
0	60626	B	0												0	0	0	0
		C	0												0	0		
1	56368	B	0												0	0	-274	-274
		C	274												274	274		
1	60868	B	280												280	280	209	209
		C	71												71	71		
1	60962	B	2,737												2,737	2,737	0	0
		C	2,737												2,737	2,737		
2	59126	B	2,576	1,869	1,277	774	418	160	146	133	120	109	99	90	7,220	7,771	7,220	7,771
		C	0												0	0		

Mode Distribution for Cell:

Mode	0	1	2	3
No.	5	3	1	0

B(10) cut off year B(4-9) cut off year

TABLE B-11. INTERVIEW SAMPLE DISTRIBUTION IN APPLICATION MODES

CELL	SIZE (n)	MODE 0	MODE 1	MODE 2	MODE 3
1976 BQ	9	.333	.333	.333	.000
1974 BQ	9	.222	.444	.222	.111
1972 BQ	9	.111	.667	.222	.000
1971 BQ	18	.167	.667	.056	.111
BQ Cells	45	.200	.556	.178	.067
1976 NBQ	9	.222	.667	.111	.000
1974 NBQ	18	.444	.444	.111	.000
1972 NBQ	9	.222	.778	.000	.000
1971 NBQ	9	.556	.333	.111	.000
NBQ Cells	45	.378	.533	.089	.000
Weighted Average*	90	.342	.538	.107	.013
1976**	18	.233	.634	.133	.000
1974	27	.413	.444	.127	.016
1972	18	.213	.769	.019	.000
1971	27	.400	.467	.089	.044

*Weighted by aggregate proportions for BQ (20%) and NBQ (80%) stratum.
**Weighted by proportions for BQ and NBQ stratum in the particular year.

Note: All entries are in the form of probabilities calculated by dividing the number in the mode by the size (n).

Distribution Tests

The Lilliefors and correlation tests for the distributions of net benefit values in each mode are shown in the following tables and figures. Further analysis of Mode 2 indicated the presence of two submodes, which may be seen in the correlation test graphs. These submodes are characterized by whether the technology application affected only one individual (probably a normal distribution) or it was institutionalized in the recipient organization and affected several production factors through more than one individual (probably a log-normal distribution). The faster rate (10 percent) of declining technological utility appears to be more appropriate when only one person is affected and the variable, industry-derived rates (4 to 9 percent) appear to be more appropriate for institutionalized applications. These observations and related hypotheses are discussed in Section IV.

TABLE B-12. DISTRIBUTION AND LILLIEFORS TEST FOR SAMPLE VALUES IN MODE 1

NET BENEFITS	STANDARD VARIABLE	CUMULATIVE NUMBER	SAMPLE CUMULATIVE PROBABILITY (A)	NORMAL CUMULATIVE PROBABILITY (B)	A-B
-1016	-2.16	1	.033	.015	.018
-547	-1.28	2	.067	.100	-.033
-443	-1.08	3	.1	.119	-.019
-351					
-351	-.91	5	.167	.181	-.014
-322	-.85	6	.2	.198	.002
-274	-.76	7	.233	.224	.009
-184	-.59	8	.267	.278	-.011
-121	-.47	9	.3	.319	-.019
-70	-.38	10	.333	.352	-.019
-66	-.37	11	.367	.356	.011
-53	-.35	12	.4	.363	.037
-13	-.27	13	.433	.394	.039
0	-.25	14	.467	.401	.066
16	-.22	15	.5	.413	.087
60	-.13	16	.533	.448	.085
126	-.01	17	.567	.496	.071
152	.04	18	.6	.516	.084
209	.15	19	.633	.560	.073
257	.24	20	.667	.595	.072
271	.27	21	.7	..606	.094
292	.31	22	.733	.622	.111
307	.33	23	.767	.629	.138
328	.37	24	.8	.644	.156*
560	.81	25	.833	.791	.042
678	1.03	26	.867	.848	.019
712	1.10	27	.9	.864	.036
876	1.41	28	.933	.921	.012
1395	2.39	29	.967	.992	-.025
1460	2.51	30	1.0	.994	.006

$\bar{x}$ = 130
S = 521

Lilliefors test result: more than 5% of normal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters μ and σ for normal population are:
$\mu = \bar{x} = 130$; $\sigma = S = 521$

* Largest difference in column.

TABLE B-13. DISTRIBUTION AND LILLIEFORS TEST FOR SAMPLE VALUES IN MODE 2: NORMAL

B(10) NET BENEFITS	STANDARD VARIABLE	CUMULATIVE NUMBER	SAMPLE CUMULATIVE PROBABILITY (A)	NORMAL CUMULATIVE PROBABILITY (B)	A-B
712	-1.37	1	.083	.085	-.002
1,160	-1.21	2	.167	.113	.054
1,562	-1.08	3	.250	.140	.110
1,992	-.93	4	.333	.176	.157
2,175	-.86	5	.417	.194	.223*
5,300	.21	6	.500	.583	-.083
5,475	.27	7	.583	.606	-.023
6,292	.55	8	.667	.708	-.041
6,496	.62	9	.750	.732	.018
7,220	.87	10	.833	.807	.026
8,320	1.25	11	.917	.894	.023
9,500	1.66	12	1.0	.951	.049

$\bar{x}$ = 4,684
S = 2,904

Lilliefors test result: more than 20% of normal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters μ and σ for normal population are:
$\mu = \bar{x} = 4,684$; $\sigma = S = 2,904$

B(4-9) NET BENEFITS					
1,134	-1.28	1	.083	.100	-.017
1,420	-1.19	2	.167	.117	.050
1,562	-1.14	3	.250	.127	.123
1,992	-1.01	4	.333	.335	-.002
3,064	-.67	5	.417	.251	.166*
5,300	.04	6	.500	.515	-.015
5,475	.10	7	.583	.539	.044
6,292	.36	8	.667	.640	.027
7,771	.83	9	.75	.796	-.046
8,320	1.0	10	.833	.841	-.008
9,500	1.37	11	.917	.914	.003
10,146	1.58	12	1.0	.942	.058

$\bar{x}$ = 5,165
S = 3,155

Lilliefors test result: more than 20% of normal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters μ and σ for normal population are:
$\mu = \bar{x} = 5,165$; $\sigma = S = 3,155$

* Largest difference in column.

TABLE B-14. DISTRIBUTION AND LILLIEFORS TEST
FOR SAMPLE VALUES IN MODE 2: LOGNORMAL

B(10) NET BENEFITS	U= Ln(x-200)	STANDARD VARIABLE	CUMULATIVE NUMBER	SAMPLE CUMULATIVE PROBABILITY (A)	NORMAL CUMULATIVE PROBABILITY (B)	A-B
712	6.24	-2.0	1	.083	.023	.06
1,160	6.87	-1.32	2	.167	.093	.074
1,562	7.22	- .93	3	.25	.176	.074
1,992	7.49	- .64	4	.333	.261	.072
2,175	7.59	- .53	5	.417	.298	.119
5,300	8.54	.5	6	.50	.691	-.191*
5,475	8.57	.53	7	.583	.702	-.119
6,292	8.71	.68	8	.667	.752	-.085
6,496	8.75	.73	9	.75	.767	-.017
7,220	8.86	.85	10	.833	.802	.031
8,320	9.00	1.0	11	.917	.841	.076
9,500	9.14	1.15	12	1.0	.875	.125

$\bar{X}$=4,684 S=2904

$\bar{U}$=8.08 S=.92

Lilliefors test result: more than 20% of lognormal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters μ and σ for lognormal population are:
μ =$\bar{U}$=8.1; σ =S=.9

B(4-9) NET BENEFITS						
1,134	6.84	-1.70	1	.083	.045	.038
1,420	7.11	-1.37	2	.167	.085	.082
1,562	7.22	-1.23	3	.25	.109	.141
1,992	7.49	- .90	4	.333	.184	.149*
3,064	7.96	- .33	5	.417	.371	.046
5,300	8.54	.38	6	.50	.648	-.148
5,475	8.57	.41	7	.583	.659	-.076
6,292	8.71	.59	8	.667	.722	-.055
7,771	8.93	.85	9	.75	.802	-.052
8,320	9.00	.94	10	.833	.826	.007
9,500	9.14	1.11	11	.917	.866	.051
10,146	9.20	1.18	12	1.0	.881	.119

$\bar{X}$=5,165 S=3,155

$\bar{U}$=8.23 S=.82

Lilliefors test result: more than 20% of lognormal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters μ and σ for lognormal population are:
μ =$\bar{U}$=8.2; σ =S=.8

* Largest difference in column.

TABLE B-15. DISTRIBUTION AND LILLIEFORS TEST
FOR SAMPLE VALUES IN MODE 3: LOGNORMAL

B(10) NET BENEFITS	U= Ln(x-1,000)	STANDARD VARIABLE	CUMULATIVE NUMBER	SAMPLE CUMULATIVE PROBABILITY (A)	NORMAL CUMULATIVE PROBABILITY (B)	A-B
10,850	9.20	-1.39	1	.333	.082	.251*
27,414	10.18	.53	2	.667	.702	-.035
32,592	10.36	.88	3	1.0	.811	.189

$\bar{X}$=23,619 $\bar{U}$=9.91
S=9,273 S=.51

Lilliefors test result: more than 20% of lognormal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters ξ and σ for lognormal population are:
$\xi=\bar{U}=9.9$; $\sigma=S=.5$

B(4-9)

22,700	9.99	-1.0	1	.333	.159	.174
27,414	10.18	-.41	2	.667	.341	.326*
47,760	10.75	1.38	3	1.0	.916	.084

$\bar{X}$=32,625 $\bar{U}$=10.31
S=10,874 S=.32

Lilliefors test result: more than 20% of lognormal population samples would have differences greater than those observed.

Maximum likelihood estimators for parameters ξ and σ for lognormal population are:
$\xi=\bar{U}=10.3$; $\sigma=S=.3$

* Largest difference in column.

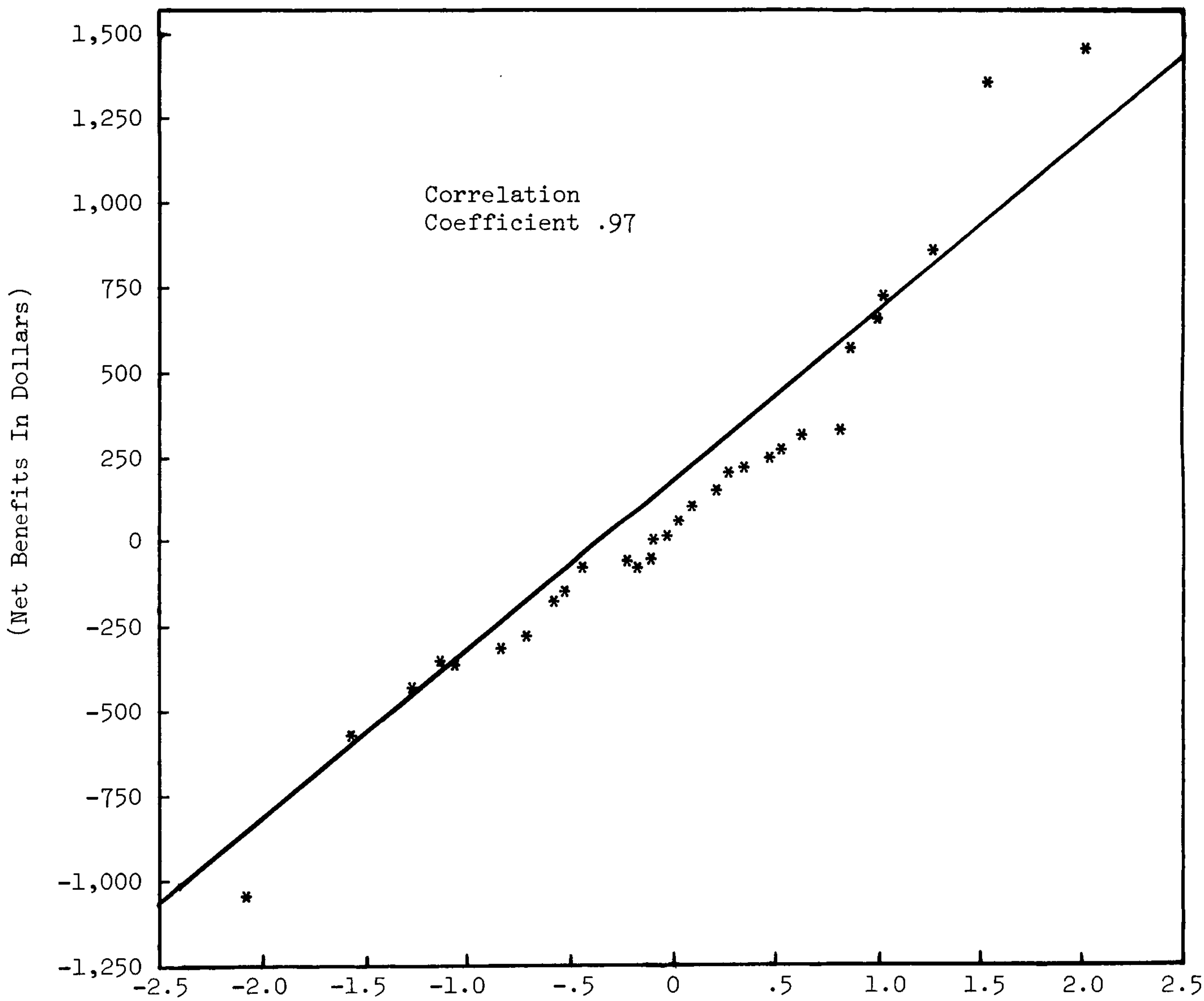
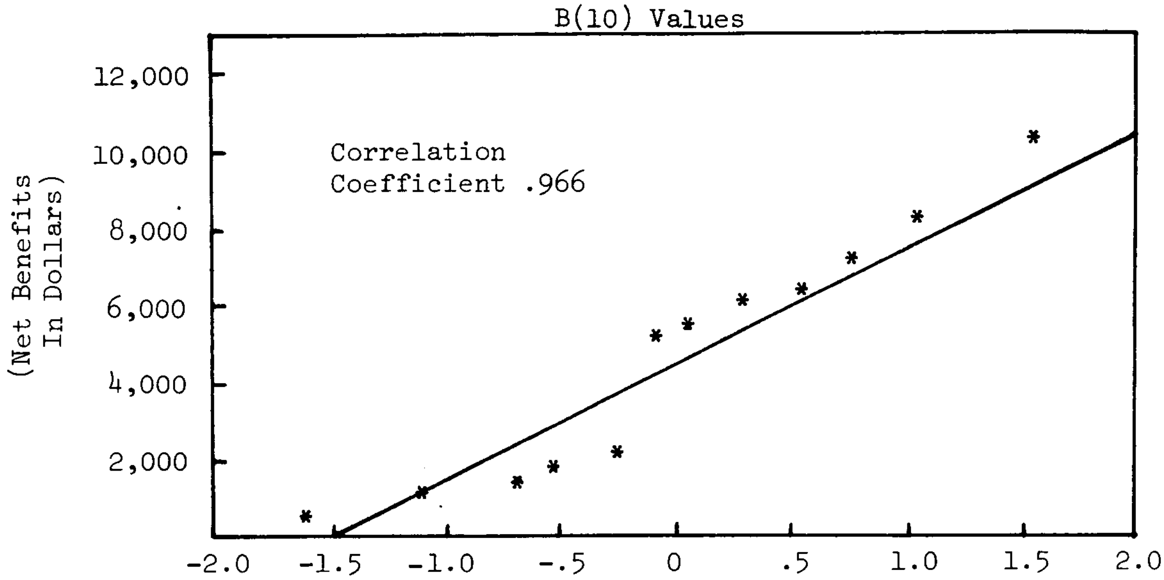


Figure B-1. Correlation Test for Mode 1 Values Compared to Normal Distribution.



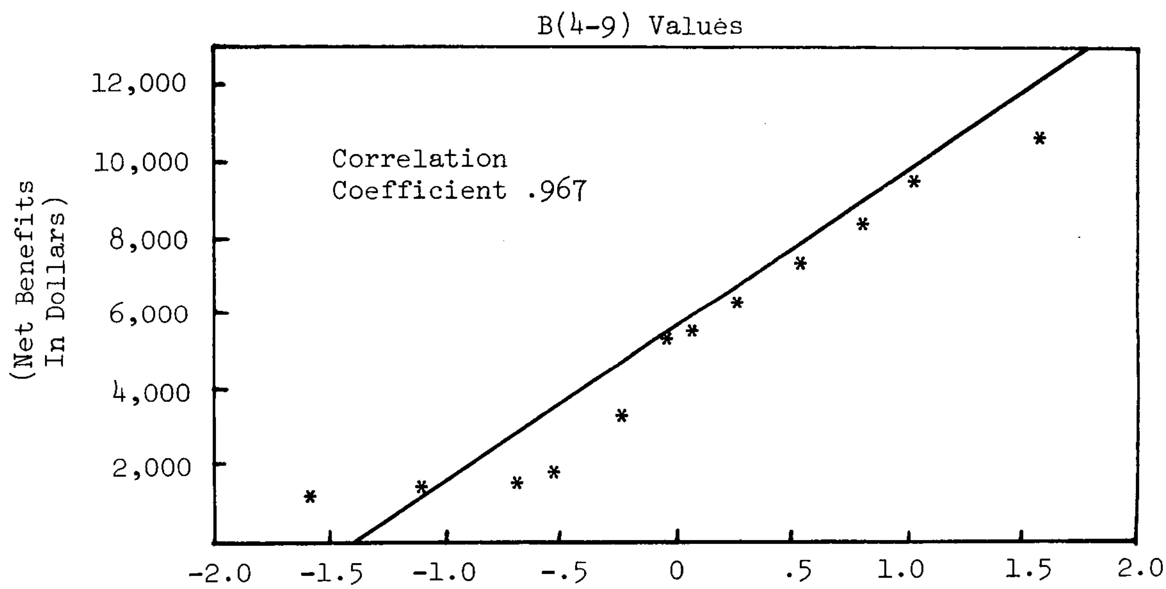
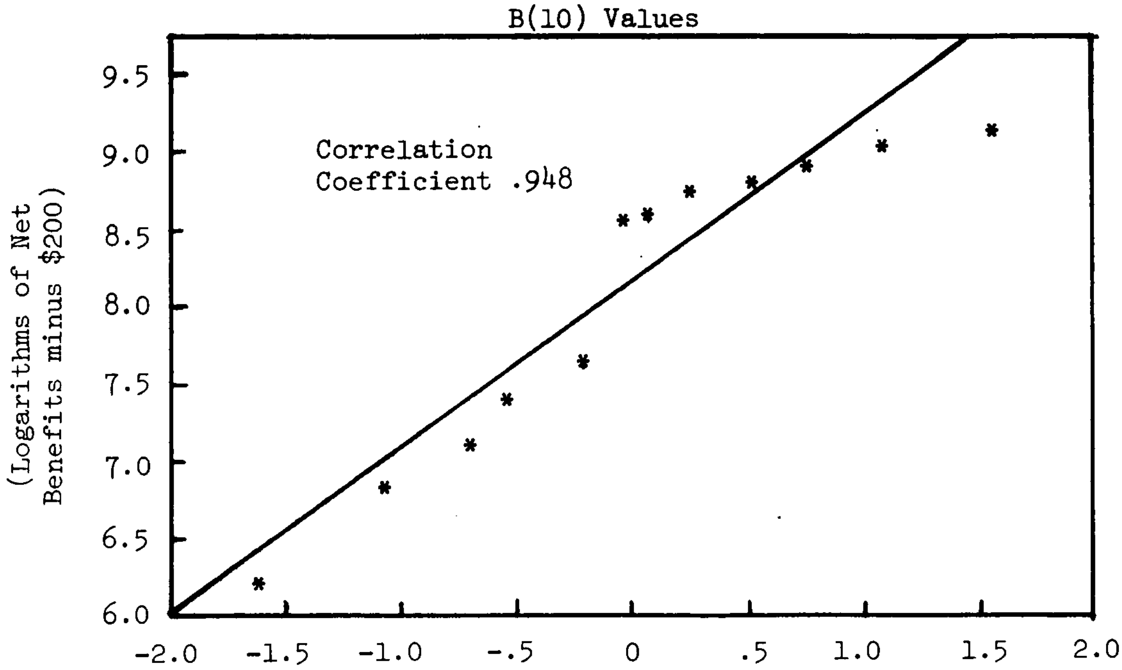


Figure B-2. Correlation Test for Mode 2 Values Compared to Normal Distrubution.



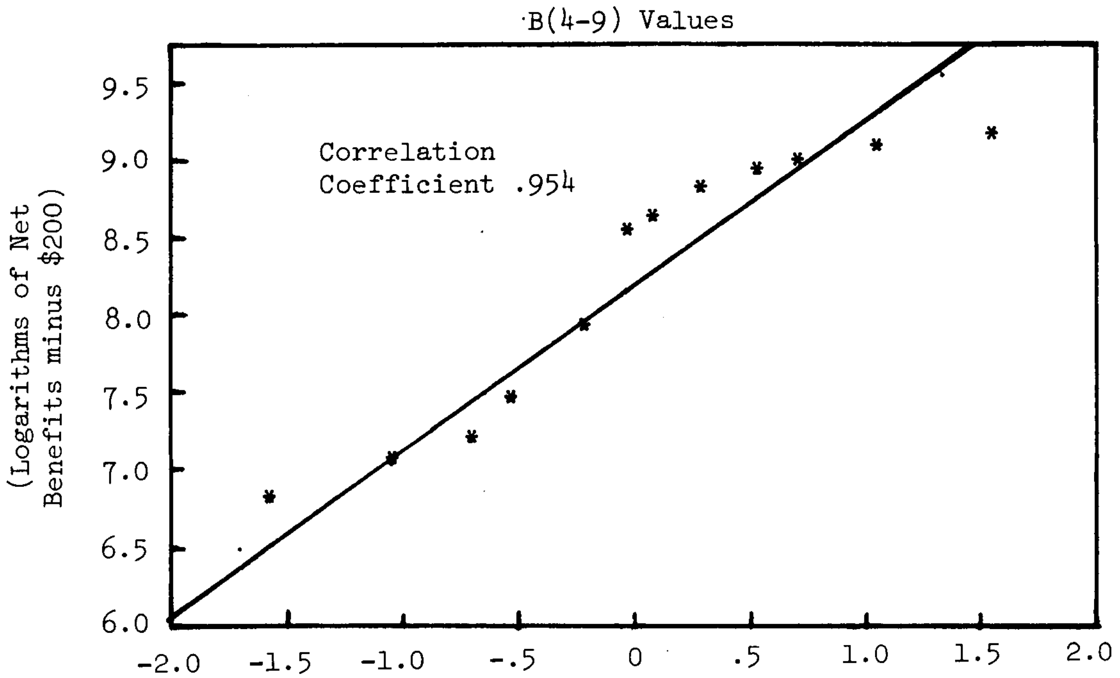
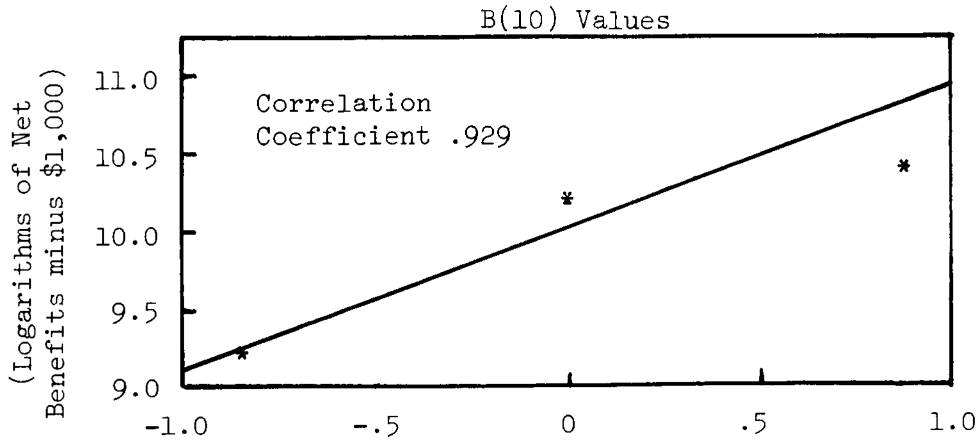


Figure B-3. Correlation Test for Mode 2 Values
Compared to Lognormal Distribution.



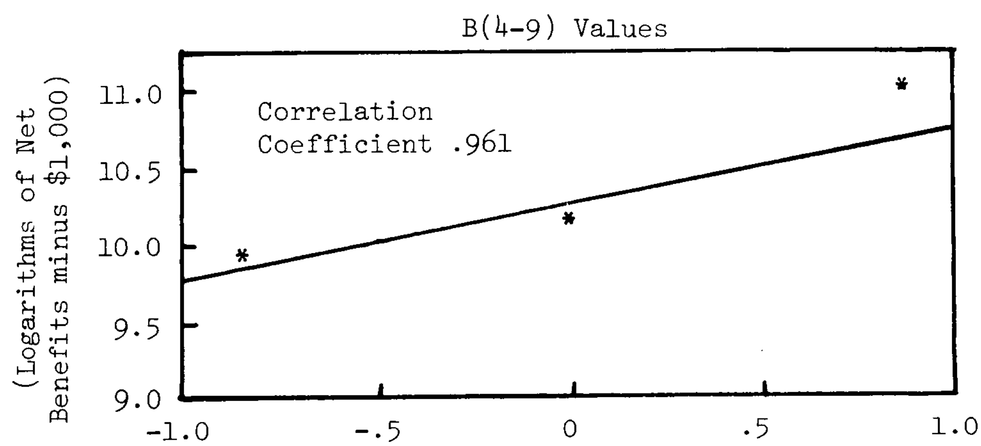


Figure B-4. Correlation Test for Mode 3 Values
Compared to Lognormal Distribution.

APPENDIX C. SURVEY TOOLS

Bureau Budget Approval No. 104-R0043

University of Denver
COLORADO SEMINARY

DENVER RESEARCH INSTITUTE UNIVERSITY PARK, DENVER, COLORADO 80210

QUESTIONS CONCERNING THE NASA TECHNICAL SUPPORT PACKAGE

We would greatly appreciate your help in providing the information requested in this questionnaire. It will be of value to NASA personnel responsible for the Technology Utilization Program. Please answer by checking appropriate boxes.

1. How did you first learn about the availability of the NASA Technical Support Package (TSP) referred to in the cover letter?

- ☐ From an engineer, scientist, or manager in my own organization
- ☐ From a librarian in my organization
- ☐ From a person outside of my organization
- ☐ Read about this TSP in a trade publication
- ☐ Read about it in a professional journal
- ☐ Read a NASA Tech Brief announcing this TSP
- ☐ Other (specify): ____________________

2. If you first learned about the TSP in a NASA Tech Brief, how did you acquire the Tech Brief?

- ☐ Did not learn about TSP in a Tech Brief
- ☐ Received the Tech Brief directly from NASA
- ☐ Received the Tech Brief as part of internal distribution within my organization
- ☐ Received it from someone outside of my organization
- ☐ Other (specify): ____________________

3. What was your most important reason for ordering this particular TSP?

- ☐ To keep abreast of developments in my field(s) of interest
- ☐ To assist in solving a specific problem or in getting the most up-to-date answer to a particular question
- ☐ To assist others in my organization in their research and development activities
- ☐ Other (specify): ____________________

4. What is your estimate of the number of hours you and other members of your organization spent in reviewing, studying or applying information contained in the TSP you ordered?

____
Hours

5. At which of these levels of scientific or technical development were you working when you requested the TSP?

- ☐ Acquiring a scientific understanding of nature (basic research)
- ☐ Demonstrating a new technical capability on a laboratory basis
- ☐ Applying new technical capability to a full-scale prototype (field trial)
- ☐ Putting new technology to its first operational use
- ☐ Other (specify): ____________________

6. What was your primary use of the information in the TSP?

- ☐ To help solve a specific technical problem
- ☐ Passed it along to someone else for possible use
- ☐ Reviewed and filed it for future reference
- ☐ Discarded it
- ☐ Other (specify): ____________________

7. If you used the TSP for problem solving, how important was it in the solution of that problem?

- ☐ Did not use it for solving a technical problem
- ☐ Not important at all (irrelevant, not applicable)
- ☐ Slightly important (less than 5% input to problem solution)
- ☐ Moderately important (about 5% to 14% input to solution)
- ☐ Quite important (15% to 49% input to solution)
- ☐ Crucial (50% or greater input to solution)

8. If any beneficial result(s) followed from your use of the TSP, please indicate which one(s):

- ☐ No beneficial results I can think of
- ☐ Kept me abreast of developments in my field(s) of interest
- ☐ Stimulated basic and applied research
- ☐ Developed new process(es) or technique(s)
- ☐ Improved existing process(es) or technique(s)
- ☐ Developed new product(s)
- ☐ Improved existing product(s)
- ☐ Reduced operating costs
- ☐ Saved time, manhours
- ☐ Increased sales
- ☐ Other (specify): ____________________

(Continued on Reverse Side)

9. If you experienced any problem(s) in trying to use information in the TSP, please indicate which one(s):

- ☐ No difficulties I can think of
- ☐ Patent clearance too complicated
- ☐ Technology in TSP was not well enough developed for my purposes
- ☐ Insufficient information in TSP
- ☐ Incorrect information in TSP
- ☐ Unusually long delay in obtaining the TSP
- ☐ Excessive adaptation costs
- ☐ Other (specify): ______________________

10. Please rate the information contained in the particular TSP you ordered in terms of each of the sets of words below. Make a check mark (✓) in the appropriate space for *each* pair of words. [Do not omit any of the items and place only one check mark on any one set of words.]

TSP RATING

important __:__:__:__:__ unimportant
old __:__:__:__:__ new
complete __:__:__:__:__ incomplete
unclear __:__:__:__:__ clear
unusual __:__:__:__:__ usual
relevant __:__:__:__:__ irrelevant
helpful __:__:__:__:__ unhelpful
superior __:__:__:__:__ inferior
useless __:__:__:__:__ useful
poor reproduction __:__:__:__:__ good reproduction

11. What type of an organization do you work for (check only one)?

- ☐ A manufacturing organization (e.g., electrical machinery, testing instruments, transportation equipment)
- ☐ A service organization (e.g., education, retail sales, business consulting, medical services, research)
- ☐ A government agency (e.g., Federal, state, local)
- ☐ Self-employed
- ☐ Other (please specify): ______________

12. How large is the organization for which you work?

- ☐ Self-employed
- ☐ 1 to 5 employees
- ☐ 6 to 49 employees
- ☐ 50 to 499 employees
- ☐ 500 to 999 employees
- ☐ 1,000 to 4,999 employees
- ☐ 5,000 to 9,999 employees
- ☐ 10,000 employees or more

13. Please check the appropriate category for your annual income level.

- ☐ Less than $12,500
- ☐ $12,500 to $19,999
- ☐ $20,000 or more

14. What is your *primary* job (check only one)?

- ☐ Engineer
- ☐ Scientist
- ☐ Manager, Supervisor
- ☐ Technician
- ☐ Librarian
- ☐ Other (please specify): ______________

15. What is the highest completed level of your formal schooling?

- ☐ Less than a bachelor's degree
- ☐ B.A., B.S., or equivalent
- ☐ M.A., M.S., or equivalent
- ☐ Ph.D. or equivalent
- ☐ Other (please specify): ______________

16. Do some of your responses contain proprietary information? If yes, please indicate which ones. No information which you identify as proprietary will be associated with you or your organization.

- ☐ Yes (specify): ______________
- ☐ No

Your Name: ______________ Your Title: ______________ Today's Date: __________

Please return completed questionnaire to:

Industrial Economics Division, TSPQ
Denver Research Institute
University of Denver
Denver, Colorado 80210

OMB Approval No. 104-R0043

COLORADO SEMINARY

UNIVERSITY OF DENVER
DENVER RESEARCH INSTITUTE

UNIVERSITY PARK • DENVER, COLORADO 80210

Industrial Economics Division

QUESTIONS CONCERNING THE NASA TECHNICAL SUPPORT PACKAGE

We would greatly appreciate your help in providing the information requested in this questionnaire. It will be of value to NASA personnel responsible for the Technology Utilization Program. Please answer by checking appropriate boxes.

1. What type of an organization do you work for (check only one)?

- ☐ A manufacturing organization (e.g., electrical machinery, testing instruments, transportation equipment)
- ☐ A service organization (e.g., education, retail sales, business consulting, medical services, research)
- ☐ A government agency (e.g., Federal, state, local)
- ☐ Self-employed
- ☐ Other (please specify): ____________________

2. What is your *primary* job (check only one)?

- ☐ Engineer
- ☐ Scientist
- ☐ Manager, Supervisor
- ☐ Technician
- ☐ Librarian
- ☐ Other (please specify): ____________________

3. What is your *primary* area of organizational operations (check only one)?

- ☐ Research
- ☐ Design and Development
- ☐ Production
- ☐ Marketing
- ☐ Other (specify): ____________________

4. How did you first learn about the availability of the NASA Technical Support Package (TSP) referred to in the cover letter?

- ☐ From an engineer, scientist, or manager in my own organization
- ☐ From a librarian in my organization
- ☐ From a person outside of my organization
- ☐ Read about this TSP in a trade publication
- ☐ Read about it in a professional journal
- ☐ Read a NASA Tech Brief announcing this TSP
- ☐ Other (specify): ____________________

5. What was your primary use of the information in the TSP?

- ☐ To keep abreast of developments in my field(s) of interest
- ☐ To assist in solving a specific problem or in getting the most up-to-date answer to a particular question
- ☐ To assist others in my organization in their research and development activities
- ☐ Other (specify): ____________________

6. Please indicate your management's degree of current interest in the technology described in the TSP. Place a check (✓) mark above only *one* of the four alternatives.

No Interest	Slight Interest	Moderate Interest	Strong Interest

7. Please assume that your acquisition, adaptation, and use of this technology could pass through four different stages: (1) initial awareness and review; (2) engineering evaluation; (3) in-house use or prototype testing; and (4) diffusion of the technology through marketing activities. Place a check (✓) mark above only *one* of the four alternatives to indicate your progression through these stages. (If your organization is no longer interested in the technology, please indicate how far you had progressed through these stages before terminating.)

Preliminary Understanding	Engineering Evaluation	In-House Use or Prototype Testing	Full-Scale Marketing

8. To which of the following objectives, if any, did the information in the TSP contribute?

- ☐ Developing a new product
- ☐ Developing an improved product
- ☐ Developing a new process
- ☐ Developing an improved process
- ☐ Improving, testing, or validating new concepts
- ☐ None of the above

(Continued on Reverse Side)

A PRIVATE INDEPENDENT UNIVERSITY

9. If you used the TSP for solving a particular technical problem, how important was it in the solution of that problem?

- ☐ Did not use it for solving a technical problem
- ☐ Not important at all (irrelevant, not applicable)
- ☐ Slightly important (less than 5% input to problem solution)
- ☐ Moderately important (about 5% to 14% input to solution)
- ☐ Quite important (15% to 49% input to solution)
- ☐ Crucial (50% or greater input to solution)

10. If any economic benefits have followed from your use of the technology described in this TSP, place a check (✓) mark by the type(s) of benefit(s) and *estimate* the total dollar amounts involved. Please indicate whether the benefits are one-time only or recurring.

	One-time	Recurring
☐ No economic benefits I can think of		
☐ Reduced operating costs–including manhours saved $ ______ (estimate)	☐	☐
☐ Produced or increased sales totaling $ ______ (estimate)	☐	☐
☐ Other (specify): ______ ______	☐	☐

11. If you experienced any problem(s) in trying to use information in the TSP, please indicate which one(s):

- ☐ No difficulties I can think of
- ☐ Patent clearance too complicated
- ☐ Technology in TSP was not well enough developed for my purposes
- ☐ Insufficient information in TSP
- ☐ Incorrect information in TSP
- ☐ Unusually long delay in obtaining the TSP
- ☐ Excessive adaptation costs
- ☐ Other (specify): ______

______

12. Should additional information concerning your use of this technology be needed, we would appreciate having your telephone number: ______

13. Today's date: ______

14. Do some of your responses contain proprietary information? If yes, please indicate which ones. No information which you identify as proprietary will be associated with you or your organization.

- ☐ Yes (specify): ______
- ☐ No

Comments (identify relevant questions if applicable):

Your Name: ______ Your Title: ______

Please return completed questionnaire to:

Industrial Economics Division, TSPQ
Denver Research Institute
University of Denver
Denver, Colorado 80210

Completed Interview ____yes ____no (10/5/76)

Cell ____(year) ____Benefits ____No Benefits

TSP COST BENEFIT STUDY - 1976

Name________________________________ Case No.______________

Address____

Position____________________________Telephone________________

General Area of Application__________________________________
(e.g., R&D for electronics manufacturer, programming for a commercial computer service, university engineering faculty)

Interview Date__________Request Date___________Questionnaire Date__________

Tech Brief No. and Title_____________________________________

____(attach copy)

1. Recalls TSP and use: ____yes ____vaguely ____no (if no, ask general question 7 and terminate interview)

2. Type of Application/Benefit (if more than one, explain relationship)

____ new product development

____ product improvement

____ product marketing

____ operating cost reduction/saving

____ R&D cost reduction/saving

____ cost avoidance

____ new service

____ improved service

____ other (explain____________________
________________________________)

____ general information only (if used, check appropriate item)

____ solving a specific problem (describe____________________)

____ making engineering decisions (explain____________________
____________________________)

____ management

____ education or personnel training

3. Estimated level of importance for the TSP in the application:

____ insignificant, ____ moderately important (5-14%), ____ significant (15-49%),

____ critical (50% or more)

4. Progress to date in applying the technology (indicate C continuing or T terminated):

____awareness ____engineering evaluation ____prototype testing ____routine use

(Proprietary information ____yes ____no)

TSP COST BENEFIT STUDY - 1976 (Continued)

5. Benefits were realized: ____one time ____several times (number) ____regularly.

____benefits are expected in the future. Estimated dates or period of

time:________________________________

6. We would like your estimate of the dollar value (please convert other quantities) for your organization's gross benefits and costs (to achieve those benefits) that you attribute to this TSP. For example, some proportion of new product sales, and production equipment expenses might be allocated to the use of this technology or some proportion of operating cost reduction and personnel training expenses. Savings in time by the recipient to acquire technical information can also be included (convert to dollars) together with how much time it took to read the TSP and acquire the information. Indicate these data in the following table, be sure to: (a) answer number 5; (b) indicate whether the dollars are in 1976, 1975 or whatever figures (we will convert to present value); and (c) use gross rather than net amounts.

	1968	1969	1970	1971	1972	1973	1974	1975	1976	Future
Gross Benefit										
User Cost										

(indicate type of $'s used, 1976, 1975, etc.)

For some types of benefit (e.g., improved services), the quantified benefits may be achieved wholly, or in part, by the recipient organization's clients or customers. Indicate in parenthesis in the same table the net benefit to these secondary users.

Alternatively, the interviewee might estimate the total net value (in 1976 dollars) from using the TSP (we prefer the data above but may have to settle for less detail) ________________ (estimate).

7. Qualitative information about the Tech Brief Program:

a) How many TSP requests over the years? ____1 only, ____2-4, ____5-10,

____more than 10

b) General assessment of the Program as a source of information:

____minor, ____sometimes useful, ____often helpful, ____regularly used as an information source for new approaches or data for technological development.

c) General assessment of information in TSP's: ____general interest only, TSP COST BENEFIT STUDY - 1976 (Continued)

(7) c) (continued)

____current awareness for aerospace technology, ____useful data and techniques not readily accessible elsewhere, ____helpful for eliminating uncertainties or resolving problems in making decisions.

d) List, in rank order, the four major sources of technical information they obtain from outside their organization (e.g., trade press, salesmen, professional societies, etc.):

i)

ii)

iii)

iv)

Estimate the percentage of new technical information obtained from TSP's as compared to all other external sources of information. __________%

e) Estimate the time spent per month in acquiring technical information from outside the organization. ______hours per month.

APPENDIX D. REFERENCES

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